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An Assessment of American plaice in NAFO Subdivision 3PS

Évaluation de la plie canadienne de la sous-division 3Ps de l'OPANO

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Abstract

The stock of American plaice in Subdivision 3Ps has been under moratorium since September 1993. Catches averaged just under 4000 t during the 1980's but rapidly declined after 1991. There has been no directed fishery since the moratorium was instituted. Catch has increased substantially since 1995, and in 2001 the catch was over 1,000 t. The catch to September 2002 was more than 900 t. The fishery has changed substantially compared to the premoratorium period with a larger inshore component, a substantial truncation in the length distribution and a much higher percentage of females in the catch. Since 1992, research vessel surveys indicate that the stock has been at a very low level. There has been a slight increase over the 1992-2002 time period in both biomass and abundance indices but average biomass over the last 3 years is only 20% and abundance 30% of the 1983-87 average. The female SSB index showed a large decline from the mid 1980's to the early 1990's and has shown a slight increase since 1997. The SSB index from 2000-2002 is 26% of the 1983-1987 average. Analyses of recruitment from survey data indicated that cohort strength declined from the 1979 to the 1995 year class. Since then cohort strength has generally increased. Although there is a broad range of observed recruitment at an SSB index below 10, recruitment level does increase with SSB and the best observed recruitment was above and SSB index of 20. The current SSB index is about 9. Catch/biomass ratio declined rapidly after 1990 as catches decreased, and reached a minimum in 1995. Catch to survey biomass ratios indicate that exploitation rate has been increasing since the mid 1990's. In the next few years the weak 1994-1997 year classes will be moving into the age range of the biomass subject to the bycatch fishery. This will likely result in a decrease in exploitable biomass. At current levels of catch this should result in a further increase in fishing mortality. More recent year classes appear stronger but these will not contribute to the exploitable biomass or SSB for several more years.

Résumé

Le stock de plie canadienne de la sous-division 3Ps de l'OPANO est sous le coup d'un moratoire depuis septembre 1993. Les prises atteignaient en moyenne un peu moins de 4 000 t pendant les années 1980, mais ont rapidement diminué après 1991. Aucune pêche dirigée n'a eu lieu depuis la mise en place du moratoire. Les prises ont considérablement augmenté depuis 1995; elles se chiffraient à plus de 1 000 t en 2001 et, en septembre 2002, elles atteignaient plus de 900 t. La pêche a beaucoup changé par rapport à la période avant le moratoire : participation accrue des pêcheurs côtiers, troncature importante de la distribution des longueurs et pourcentage nettement plus élevé de femelles dans les prises. Depuis 1992, les relevés de navire de recherche indiquent que les effectifs du stock sont très faibles. Les indices de biomasse et d'abondance ont légèrement augmenté entre 1992 et 2002, mais la biomasse et l'abondance moyennes au cours des trois dernières années ne se situaient respectivement qu'à 20 % et 30 % de la moyenne pour 1983-1987. L'indice de la BSR pour les femelles a fortement diminué du milieu des années 1980 au début des années 1990, pour ensuite légèrement augmenté depuis 1997. L'indice de la BSR pour 2000-2002 se situe à 26 % de la moyenne pour 1983-1987. Les analyses du recrutement reposant sur des données de relevé indiquent que l'abondance des cohortes issues des classes d'âge 1979 à 1995 a diminué, mais qu'elle a généralement augmenté depuis. Bien qu'il y ait une vaste gamme de recrutement observé à un indice de la BSR inférieur à 10, le niveau de recrutement augmente en fonction de la BSR, le meilleur recrutement observé se manifestant lorsque l'indice était supérieur à 20. Il se situe actuellement à environ 9. Le rapport entre les prises et la biomasse a rapidement diminué après 1990 au fur et à mesure que les prises ont diminué, atteignant un creux en 1995. Les rapports entre les prises et la biomasse établie par relevés indiquent que le taux d'exploitation augmente depuis le milieu des années 1990. Au cours des quelques prochaines années, les classes d'âge 1994 à 1997, peu abondantes, seront recrutées à la plage d'âges de la biomasse soumise à des prises accessoires, ce qui résultera en une baisse de la biomasse exploitable et, aux niveaux actuels des prises, à une augmentation de la mortalité par pêche. Les classes d'âge plus récentes semblent plus abondantes, mais elles ne contribueront pas à la biomasse exploitable ou à la BSR avant plusieurs années.

Description of the Fishery

Catches from this stock were highest from 1968 to 1973, exceeding 12,000 t on three occasions in this period (Fig. 1, Table 1). Catches by non-Canadian vessels peaked at about 8800 t in 1968, due mainly to the USSR catch, and have not exceeded 800 t since 1973. Since 1977 only Canada and France have been involved in this fishery. Catches averaged just under 4000 t during the 1980's but rapidly declined after 1991. Based on a recommendation by the FRCC the fishery was closed in September of 1993 for the remainder of that year. Since that time catch is supposed to be bycatch only. Catch has increased substantially since 1995, and in 2001 the catch was over 1,000 t. The catch to September 2002 was more than 900 t.

Data from the Newfoundland reported catch statistics (ZIFF) were examined to determine which fisheries were taking the greatest portion of the American plaice bycatch. The bycatch of American plaice is taken in two main fisheries, the directed cod and the directed witch flounder fisheries. Since 1999 the bycatch of plaice as a percentage of the directed species has been well over 20 % in the witch flounder fishery (Table 2). In the cod fishery it was less than 5% overall, except for 2002 when the percentage was 6.5. During this period 1/4 to 1/3 of the total American plaice catch has come from the witch flounder fishery. At the same time the TAC for cod has ranged from 15 000 to 30 000 t while the quota for witch flounder has been 650 t. The data for 2002 only include January to August and so the percentages will likely change when all data are available. For data where main species sought was recorded as witch flounder, catches came from the otter trawl and Danish seine fleets. The bycatch percentage in the otter trawl fishery has been extremely high and in 2000 and 2001 more American plaice was caught than witch flounder in that fishery (Table 3). The directed witch fishery using Danish seines has had a much lower bycatch percentage, generally 5% or less.

Length and age compositions from commercial fisheries

Length frequency data were collected from various fisheries on American plaice in Subdiv. 3Ps during 1999-2002. Otoliths were also collected during these years, but only those from 2000 onward have been aged. Despite the predominance of fixed gear landings each year, the only year with samples from these gear sectors was 2000, when some length frequencies were collected from line trawl catches. Most of the available length frequencies were collected by observers, from American plaice caught in other directed fisheries, primarily the Canadian otter trawl (OT) fishery for witch flounder in the first quarter of each year. Fig. 2 shows a comparison of OT length frequencies collected in February of each year 1999-2002. Peak lengths ranged between 36 and 44 cm, with the length frequency for Feb. 2000 being shifted towards larger fish.

The number of larger fish in the catches in recent years remains lower than in the years prior to the mid 1990's. This is readily seen in Fig 3, which shows a comparison of length frequencies from 1990, 1998, and 2002. There has been a reduction in the length of the largest fish, both male and female, observed in the commercial catches since the early 1990's, with the largest fish in catches during 2000-02 being 10-20 cm smaller than the

largest fish from catches in the mid 1980's (Fig. 4). Corresponding with the reduction in the catches of larger males was an increase in the percentage of females in the catches, from around 70% in 1983-93 to over 85% from 1994 to 2001. One possible cause of this shift was the adoption of a minimum mesh size of 145 mm by the Canadian otter trawlers, which was required as a result of conservation harvesting plans (CHP's) introduced in 1994. Prior to this, the regulated minimum mesh size was 130 mm. Although there has been a declining trend in the percentage of females since 1996, recent values are still above those observed in 1988-93 (Fig. 5). Some of the differences may also be due to the change in the nature of the fishery since 1993 (by-catch vs. directed), as well as the reduced sampling in the latter period. In any case, it is clear from available data that length compositions after 1993 were much different than those observed previously.

Table 4 shows the catch at age, and mean lengths and weights at age calculated from the samples collected during 2000 to 2002. The differences in the age compositions among years are partly due to the lack of fixed gear samples in 2001 and 2002. For 2000, the difference in the age compositions in the catches of line trawl (applied to 358 tons of fixed gear catch) and otter trawl (applied to the remaining 292 tons of catch) can be seen in Fig 6. Based on this comparison, it is highly probable that the age compositions calculated for 2001 and 2002 under estimate the numbers of older fish and over estimate the numbers of younger fish in the catches.

In the 1999 assessment of this stock (Morgan et al 1999), it was concluded that there have been major changes in the commercial fisheries and the resulting length compositions taken from these fisheries during the 1990's, and therefore it was not advisable to apply historic length and age compositions to the recent catch data. Minimal sampling of fixed gear catches is available after 1993, even though these gears took the majority of catches since then. In addition, no otolith readings are available from the commercial fishery on this stock for the period 1994 to 1999. For these reasons, it is not possible to construct representative catch at age for American plaice in Subdiv. 3Ps for the years 1994-99 with available data. Catch at age and mean weights at age are available for this stock for the years 1974-93 (Morgan et al 1995), and are given in Tables 5 and 6.

Research Vessel Surveys

Stratified-random surveys have been conducted by Canada in Subdivision 3Ps in each year from 1972 to 2002, based on the stratification scheme shown in Figure 7. Coverage prior to 1980 was poor. There were two surveys in 1993, one in February and one in April. Most of the surveys prior to 1993 were in February/March, while those since 1993 have been in April. The data can be split into three time periods based on the trawl used in each period: 1971-82 was Yankee 36, 1983-95 was Engel 145 and 1996-2002 was Campelen 1800 (see McCallum and Walsh (1996) for a description of the various trawls). There is a conversion between the second and third survey gears (Morgan et al. 1999) but not the first and third. Therefore, abundance and biomass indices in this document are reported from 1983 to 2002.

Current survey indices have been compared with the 1983-1987 time period throughout the document. This is the beginning of the Campelen or equivalent time series. The previous Engel time series showed that the 1980's were a period of relative stability with the 1983-1987 portion of the decade being about average. The area was surveyed in the 1970's but areal coverage was so poor that results are not comparable with the later surveys.

Trends in Biomass and Abundance

Biomass and abundance indices from 1983-2002 are shown in Figure 8. Mean number and weight per stratum for 1996-2002 are given in Tables 7 and 8. From the mid 1980's to 1990 there was a large decline in the indices. Since 1992 stock size has been very low. There has been a slight increase over the 1992-2002 time period in both biomass and abundance indices but average biomass over the last 3 years is only 20% and abundance 30% of the 1983-87 average. For only the 7+, or exploitable, portion of the survey index, the biomass is 19% and the abundance 18% of the 1983-87 average.

Abundance at age from 1983-2002 is given in Table 9. From 1994 to 1997 there were no fish older than age 14. The percentage of 9+ fish was extremely low in 1996 and 1997 but returned to average levels after that. The oldest age in the survey was 17 or greater in each of the last 3 years.

American plaice are distributed throughout Subdivision 3Ps (Fig. 9 & 10). There were few sets that contained no fish. In most years the area of highest concentration appeared to be the eastern portion of the Subdivision and along the western slope of St. Pierre Bank.

Mortality

Estimates of total mortality ($\log(n/n+1)$) from the Campelen or equivalent survey data were calculated for ages 2 to 17 (Fig. 11). A Lowess smoother has been added to the plots to help visualize trends. For most ages mortality increased until the early to mid 1990's before declining in recent years. The average mortality on ages 6-13 in 1994-95 was –1.0, despite very low catches. There is an indication of an increase in mortality in the last few years that is not reflected in the smoother. Average mortality on ages 6-13 increased from –0.1 in 1996-1998 to –0.4 in 1999-2001.

Mean Length and Weight at Age

Mean lengths and weights at age by sex were calculated from survey data for 1983-2002 and 1990-2002 respectively. Means were calculated accounting for the length stratified sampling design. The results are presented in Figures 12 and 13. The effect of year on mean length and weight at age was tested in two way analyses of variance including an age and year effect. There was a significant difference in mean length over the time period for both males ($F_{19,240}=6.37$, $p<0.0001$) and females ($F_{19,321}=9.08$, $p<0.0001$). There was also a significant difference in mean weight over the time period for

males ($F_{12,146}$=3.21, p<0.001) and females ($F_{12,189}$=4.36, p<0.0001). There appears to be some increase in mean length and perhaps mean weight at age during the mid 1990's, but, there were no consistent trends in either mean length or mean weight at age across the entire time period.

Maturities

Age and length at 50% maturity were estimated from survey data. Estimates of proportion mature at each age were also produced for use in spawning stock biomass calculations. Proportion mature at age was calculated according to the method of Morgan and Hoenig (1997) accounting for the length stratified sampling design. All estimates were produced by cohort.

A_{50} for both males and females has declined (Fig. 14). There was a significant difference in proportion mature at age across cohort for both males (χ^2=440.1, df=32, p<0.0001) and females (χ^2=1091.1, df=33, p<0.0001) The current A_{50} for males is about 4 years compared to 7 years at the beginning of the time series. For females the current A_{50} is about 8.5 years compared to 11 years for the earliest cohorts in the time series.

There was a significant effect of cohort on L_{50} for both sexes (males: χ^2=872.5, df=32, p<0.0001; females: χ^2=595.5, df=34, p<0.0001) (Fig. 15). The current L_{50} for males is 19-20 cm compared to 27 cm at the beginning of the time series and for females it is 36-37 cm compared to 40 cm.

Spawning Stock Biomass

Female spawning stock biomass (SSB) was calculated using survey data from 1983 to 2002. The estimates of maturity and mean weight at age described above were used, along with female abundance at age. When estimates of mean weight at age were not available for a given age in a given year, the average of the observations for that age were used.

SSB trends are very similar to those for the biomass index as a whole (Fig. 16). The female SSB index showed a large decline from the mid 1980's to the early 1990's and has shown a slight increase since 1997. The SSB index from 2000-2002 is 26% of the 1983-1987 average.

Recruitment

A model estimating cohort strength using Campelen or equivalent data showed pattern in the residuals. Therefore cohort strengths were estimated using the following model using Engel data from 1983-95 and Campelen from 1996 to 2002:

$$\log(N_{s,a,y}) = \mu + Y_y + (SA)_{s,a} + \varepsilon_{s,a,y},$$

where:

μ = intercept

s = survey subscript, Engel or Campelen

a = age subscript, age 2 to 5

y = cohort subscript

N = Index (Abundance in millions)

Y = cohort effect

SA = Survey * Age effect, and

ε = residuals from the fitted model.

Only those cohorts that were observed at least twice in the data were used. This model had no obvious pattern in the residuals (Fig. 17) and a significant cohort effect.

R^2=0.93, n=66

Source	DF	Type III SS	F value	Pr>F
COHORT	20	28.0	2.15	0.02
AGE*SURVEY	7	131.2	18.7	0.0001

Cohort strength declined from the 1979 to the 1995 year class. Since then cohort strength has generally increased.

Stock/Recruit

Relative cohort strength is plotted against the respective index of SSB in Figure 18. Although there is a broad range of observed recruitment at an SSB index below 10, recruitment level does increase with SSB and the best observed recruitment was above an SSB index of 20.

The estimates from the relative cohort strength model were used to produce recruitment in terms of numbers of 5 year olds. A Ricker stock/recruit model was fit to these data and the female SSB index, using maximum likelihood estimation. The fitted model showed a clear increase in recruitment with SSB and a maximum recruitment of 106 million 5 year olds. Although the model is fit with few data points in the range of maximum, the maximum estimated from the model is similar to the cohort strength model estimate for the 1984 year class and less than the estimates for the 1979-1981 year classes which were not used in the model fit.

A reference point suggested by Mace (1994) was applied to these data. This reference point is the SSB which produces 50% of the maximum recruitment estimated from a S/R curve. Since below this reference level productivity will be impaired, it can be considered a limit reference point (Shelton and Rice, 2002). In this analysis an SSB index of about 19, gives a recruitment that is 50% of the maximum estimated (Fig. 19).

Production Model

Various formulations of a production model using survey and catch data were attempted with ASPIC (Prager, 1994, 1995). All formulations showed poor model fit and were not considered reliable. There were strong patterns in the residuals, very low r^2 in the goodness of fit tests and often contradictory model results.

Catch to Survey Biomass

As a proxy for fishing mortality on this stock, the ratio of catch to biomass from Canadian research vessel surveys was examined from Campelen data from 1983 to 2002 (Fig. 20). Catch/biomass ratio increased steadily through the 1980's reaching a peak of 0.31 in 1990. It declined rapidly after that as catches decreased, and reached a minimum in 1995. Since then there has been a fairly steady increase in C/B as catches have increased. Levels of the last few years are similar to those in the early to mid 1980's when there was a directed fishery on this stock. The pattern and level of C/B were very similar if total or exploitable survey biomass were used in the calculations.

The biomass in the 1990 survey of 3Ps was low compared to 1989 and 1991. This may have artificially inflated the estimate of the C/B ratio in that year. If the biomass in 1990 is estimated to be between those of the adjacent years then the C/B ratios in that year would be 0.14.

Assessment

Indices of abundance and biomass showed a large decline from the mid 1980's to 1990. Since 1992 stock size has been very low. There has been a slight increase over the 1992-2002 time period in both biomass and abundance indices but average biomass over the last 3 years is only 20% and abundance 30% of the 1983-87 average. The most recent year classes have been about average despite a low SSB. For most ages total mortality has increased in the last 3 to 4 years. Catch has increased from 90 t in 1995 to over 1000 t in 2001. Catch to survey biomass ratios indicate that exploitation rate has been increasing since the mid 1990's. In the next few years the weak 1994-1997 year classes will be moving into the age range of the biomass subject to the bycatch fishery. This will likely result in a decrease in exploitable biomass. At current levels of catch this should result in a further increase in fishing mortality. More recent year classes appear stronger but these will not contribute to the exploitable biomass or SSB for several more years.

Although most of the catch has come from cod directed fisheries, in the last 3 years 25 to 30 percent of the total American plaice catch has been taken in the directed witch flounder fishery being conducted by the otter trawl fleet. While the allowable bycatch of American plaice in this fishery is 50%, compared to 10% in other fisheries, actual bycatch rates have been in the range of 93 to 143% in the last 3 years. If bycatch in this fishery were limited to levels similar to other fisheries, the total catch of American plaice could decrease by more than 20%. This should result in increased prospects for stock rebuilding.

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Table 1. Catches (1960-2002) and TACs (1974-2002) of American plaice in NAFO Subdivision 3Ps. All values in metric tons.

Year	Canada			France	USSR	Other	Total	
	Nfld	M&Q	Total					
	TAC							
1960	422	405	827	60	-	-	887	-
1961	764	660	1.424	31	-	-	1.455	-
1962	659	363	1.022	2	-	-	1.024	-
1963	504	25	529	208	1	16	754	-
1964	1.132	230	1.362	152	-	28	1.542	-
1965	574	1.275	1.849	162	-	11	2.022	-
1966	1.162	1.332	2.494	667	218	27	3.406	-
1967	2.201	1.074	3.275	533	678	8	4.494	-
1968	4.007	1.516	5.523	524	8.233	-	14.280	-
1969	2.888	1.178	4.066	245	2.180	-	6.491	-
1970	7.368	4.227	11.595	397	336	-	12.328	-
1971	4.667	1.286	5.953	820	409	-	7.182	-
1972	4.301	1.621	5.922	383	220	13	6.538	-
1973	10.972	1.840	12.812	547	1.368	42	14.769	-
1974	5.887	443	6.330	268	-	-	6.598	11.000
1975	2.517	1.301	3.818	65	128	200	4.211	11.000
1976	5.302	128	5.430	5	9	14	5.458	8.000
1977	4.235	307	4.542	63	-	-	4.605	6.000
1978	3.419	192	3.611	47	-	-	3.658	4.000
1979	3.405	187	3.592	74	-	-	3.666	4.000
1980	2.516	213	2.729	206	-	-	2.935	5.000
1981	2.703	57	2.760	457	-	-	3.217	5.000
1982	1.823	46	1.869	317	-	-	2.186	5.000
1983	1.421	83	1.504	222	-	-	1.726	5.000
1984	2.487	138	2.625	338	-	-	2.963	5.000
1985	3.608	206	3.814	406	-	-	4.220	5.000
1986	4.367	98	4.465	665	-	-	5.130	5.000
1987	4.669	119	4.788	543	-	-	5.331	5.000
1988	3.745	56	3.801	605	-	-	4.406	5.000
1989	3.102	96	3.198	759	-	-	3.957	5.000
1990	3.880	226	4.106	739	-	-	4.845	4.000
1991	3.982	76	4.058	337	-	-	4.395	4.000
1992	2.380	290	2.670	9	-	-	2.679	4.000
1993	723	57	780	-	-	-	780	3.000
1994	112	11	123	-	-	-	123	500[b]
1995	80	10	90	-	-	-	90	100[b]
1996	112	3	115	-	-	-	115	100[b]
1997	213	7	220	23	-	-	243	100[b]
1998	405	2	407	16	-	-	423	0
1999	615	14	629	25	-	-	654	0
2000	609	1	610	40	-	-	650	0
2001[a]	884	24	908	102	-	-	1010	0
2002[a,c]	875	4	879	53	-	-	932	0

[a]Provisional
[b]By-catch
[c]Data for 2002 are incomplete

Table 2. Weight of American plaice caught (t), percentage American plaice of the main species sought, and percentage of the overall American plaice catch for the year, where main species sought was identified as witch flounder or cod. Data are for Newfoundland vessels only. Data for 2002 include only catches from January through August.

	Tons of plaice	% bycatch	% of total plaice catch for year
Witch directed			
1999	184	37	28
2000	203	66	31
2001	243	65	24
2002	300	77	32
Cod directed			
1999	442	2	68
2000	335	2	52
2001	478	4	47
2002	382	6	40

Table 3. Weight of American plaice caught (t) and percentage of main species sought for data where witch flounder was identified as the directed species for the otter trawl and Danish seine fleets. Data are for Newfoundland vessels only. Data for 2002 include only catches from January through August.

	Tons of plaice	% bycatch
Otter trawl fleet		
1999	118	46
2000	200	143
2001	235	101
2002	296	93
Danish seine fleet		
1999	6	3
2000	3	2
2001	8	6
2002	4	5

Table 4. Catch at age (000 s of fish), mean lengths (cm) and weights (kg) of American plaice caught in Subdiv. 3Ps during 2000-2002. SOP is the sum of products (catch number X mean weight).

	2000	Mean			**2001**	Mean			**2002**	Mean		
Age	Catch	Length	Weight	SOP	Catch	Length	Weight	SOP	Catch	Length	Weight	SOP
6	1	33.8	0.341	0.3								
7	6	34.6	0.380	2.3	25	33.9	0.352	8.8	17	34.2	0.352	6.0
8	35	36.9	0.463	16.2	102	35	0.387	39.5	145	35.4	0.404	58.6
9	61	38.1	0.516	31.5	369	37.4	0.482	177.9	318	37.3	0.478	152.0
10	131	41.6	0.692	90.7	427	40.3	0.618	263.9	227	38.7	0.540	122.6
11	170	45.2	0.912	155.0	285	43.1	0.768	218.9	293	42.5	0.736	215.6
12	114	47.6	1.077	122.8	140	46.2	0.972	136.1	169	45.7	0.932	157.5
13	109	50.4	1.296	141.3	71	49.3	1.203	85.4	79	48.4	1.133	89.5
14	30	53.9	1.620	48.6	30	52.4	1.482	44.5	39	51.7	1.405	54.8
15	12	57.3	1.968	23.6	13	55.9	1.812	23.6	12	55.5	1.819	21.8
16	8	58.3	2.082	16.7	2	59.1	2.203	4.4	7	58.5	2.117	14.8
17	1	60.5	2.349	2.3	1	60.5	2.349	2.3	4	60.4	2.348	9.4
18	1	60.5	2.349	2.3	2	62.5	2.617	5.2	1	58.5	2.100	2.1
19									<0.5	66.5	3.216	1.6
		Catch = 650 t		653.6		Catch = 1010 t		1010.4		catch=932 t		906.3

Table 5. Catch at age, 000's of fish, for Subdiv. 3Ps A. plaice during fisheries from 1974 – 93.

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
6	326	391	121	18	49	130	2	8	2	5
7	903	839	445	133	196	240	121	89	28	83
8	889	721	1117	330	482	574	491	434	186	401
9	1140	644	1514	803	964	908	737	1032	377	476
10	1263	383	1266	905	1011	820	725	670	774	670
11	717	423	979	952	756	608	600	466	1103	501
12	792	490	715	343	726	349	545	291	447	328
13	801	361	460	288	324	225	364	297	191	256
14	422	258	223	245	225	149	71	369	121	89
15	186	61	162	223	123	117	81	341	43	15
16	198	91	127	235	75	43	50	143	21	12
17	132	79	50	157	20	23	23	104	12	3
18	137	51	41	102	11	3	14	38	5	1
19	57	44	2	34	6	1	1	20	1	1

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
6	4	3	3	5	13	10	30	26	2	8
7	14	28	90	90	181	195	232	181	44	36
8	107	378	357	277	842	563	743	852	233	202
9	603	995	613	349	1167	570	884	1444	665	303
10	1151	1214	949	521	1164	667	923	1305	660	301
11	1203	1008	1133	621	958	703	746	846	401	105
12	656	579	917	834	651	532	543	583	265	68
13	351	290	397	681	321	451	347	239	155	32
14	230	193	335	580	197	320	251	155	111	26
15	110	130	175	396	132	173	216	68	70	28
16	42	68	72	195	47	58	86	22	56	11
17	12	45	21	95	14	9	12	4	22	10
18	6	17	7	53	1	1	2	1	15	2
19	1	4	1	1	0	0	0	0	1	0

Table 6. Mean weight at age. (kilograms). for Subdiv. 3Ps A. plaice during fisheries from 1974 – 93.

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
6	0.276	0.277	0.285	0.250	0.295	0.348	0.151	0.283	0.288	0.271
7	0.343	0.381	0.335	0.301	0.306	0.428	0.316	0.301	0.405	0.396
8	0.414	0.515	0.419	0.330	0.370	0.453	0.372	0.362	0.400	0.438
9	0.516	0.561	0.522	0.415	0.469	0.560	0.469	0.433	0.428	0.534
10	0.685	0.760	0.626	0.620	0.551	0.731	0.547	0.604	0.491	0.645
11	0.855	0.852	0.797	0.747	0.783	0.989	0.756	0.756	0.629	0.686
12	1.109	1.220	0.998	1.011	0.940	1.290	0.938	0.922	0.890	0.824
13	1.377	1.368	1.238	1.362	1.105	1.729	1.313	0.862	1.143	0.913
14	1.790	1.621	1.474	1.560	1.197	2.084	2.025	0.958	1.492	1.458
15	2.004	1.997	1.682	1.779	1.716	2.320	2.037	1.164	1.919	1.866
16	2.540	2.334	1.981	2.010	2.409	2.902	2.453	1.619	2.273	2.348
17	2.530	2.613	2.367	2.294	2.624	3.124	2.898	1.849	2.665	2.781
18	3.163	2.963	2.932	2.662	2.662	2.902	3.103	2.204	3.244	3.640
19	3.740	2.890	3.352	3.159	4.021	3.124	3.103	2.633	3.568	4.687

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
6	0.263	0.192	0.278	0.235	0.281	0.242	0.285	0.279	0.303	0.251
7	0.288	0.259	0.346	0.320	0.303	0.308	0.345	0.299	0.323	0.282
8	0.340	0.341	0.427	0.400	0.382	0.392	0.419	0.390	0.379	0.353
9	0.401	0.462	0.533	0.513	0.494	0.562	0.551	0.531	0.489	0.44
10	0.492	0.620	0.673	0.623	0.648	0.692	0.663	0.687	0.641	0.595
11	0.612	0.851	0.819	0.738	0.818	0.863	0.894	0.892	0.873	0.822
12	0.809	1.172	1.113	0.938	1.082	1.114	1.220	1.178	1.114	1.022
13	1.036	1.475	1.407	1.168	1.325	1.362	1.604	1.534	1.421	1.323
14	1.270	1.850	1.805	1.497	1.627	1.780	2.077	1.960	1.761	1.752
15	1.712	2.289	2.252	1.901	2.064	2.254	2.635	2.253	2.036	1.96
16	2.355	2.665	2.762	2.450	2.603	3.078	3.300	2.809	2.618	2.203
17	2.538	3.139	3.478	3.107	3.313	3.504	4.160	3.596	3.002	2.762
18	3.034	3.366	3.772	3.511	4.148	4.489	5.124	3.216	3.376	2.906
19	3.212	3.545	5.118	4.116					3.549	

Table 7. Mean number per tow and number of sets by stratum from Canadian RV surveys in Subdivision 3Ps from 1996 to 2002.

Depth range	Stratum	Year	1996		1997		1998		1999		2000		2001		2002	
		Units	Number	Sets	Number	Sets	Number	Sets	Number	Sets	Number	Sets	Number	Sets	Number	Sets
<=56	314	133984	2.00	8	0.14	7	5.51	7	15.19	8	9.00	7	2.71	7	1.80	8
	320	181581	14.43	10	0.67	9	9.64	11	19.63	8	15.00	11	13.50	10	32.43	10
57 - 91	293	21872	-	-	0.44	2	0.89	2	2.00	2	4.50	2	1.00	2	2.00	2
	308	15407	2.00	2	2.00	2	1.00	2	33.00	2	13.00	2	6.00	2	3.00	2
	312	37417	15.33	3	0.50	2	9.33	2	11.89	2	8.89	2	6.50	2	2.00	2
	315	113763	61.57	6	5.00	6	41.86	7	38.24	7	142.00	7	47.29	7	25.98	7
	321	163560	11.67	9	13.91	9	7.30	10	23.63	9	58.20	10	10.67	9	9.90	10
	325	129858	10.38	9	50.17	6	23.86	8	52.01	8	52.00	8	57.00	8	17.63	8
	326	22835	12.50	2	5.00	2	11.00	2	22.33	2	12.72	2	30.50	2	17.50	2
	783	31501	-	-	0.00	2	0.44	2	1.00	2	3.50	2	5.50	2	3.50	2
93 - 183	294	18571	-	-	1.50	2	10.33	2	7.50	2	31.78	2	10.50	2	17.50	2
	297	20909	-	-	16.00	2	15.50	2	12.11	2	23.21	2	2.50	2	16.50	2
	307	54337	2.17	4	0.00	3	3.56	3	15.38	3	4.00	3	1.22	3	0.67	3
	311	43607	29.00	3	36.50	2	64.74	3	29.19	3	347.00	3	28.33	3	20.33	3
	317	26549	148.00	2	25.50	2	164.00	2	104.00	2	513.00	2	448.50	2	38.50	2
	319	135360	217.84	8	42.47	8	117.13	8	69.72	8	36.19	8	138.50	8	97.13	8
	322	215558	45.16	11	11.44	11	5.73	13	34.46	12	99.45	11	28.75	12	12.46	13
	323	95743	91.74	5	29.00	4	49.57	6	105.19	6	353.63	5	143.33	6	58.00	6
	324	67955	108.33	3	19.00	3	9.75	4	92.07	4	2.50	4	4.25	4	43.75	4
	781	61352	97.07	2	3.50	4	2.14	4	15.00	4	7.17	4	43.25	4	2.25	4
	782	25174	-	-	13.00	2	8.50	2	19.00	2	42.61	2	15.00	2	51.50	2
184 - 274	295	28750	-	-	42.11	2	43.67	2	37.11	2	73.10	2	10.89	2	36.00	2
	298	23523	-	-	11.50	2	8.44	2	4.00	2	8.17	2	8.00	2	17.72	2
	300	29851	-	-	1.33	2	5.33	2	6.50	2	3.72	2	1.78	2	1.50	2
	306	49935	5.82	3	5.00	3	3.05	3	6.41	3	6.04	3	3.33	3	3.70	3
	309	40718	6.26	3	2.72	2	9.33	2	1.00	2	7.24	2	6.00	2	4.00	2
	310	23385	8.50	2	7.11	2	22.39	2	6.50	2	8.50	2	30.28	2	11.89	2
	313	22698	15.56	2	4.50	2	31.11	2	5.50	2	9.50	2	21.67	2	17.50	2
	316	25999	34.00	2	67.00	2	41.00	2	1.69	2	0.00	2	10.50	2	62.00	2
	318	17745	36.50	2	49.50	2	45.50	2	9.14	2	11.17	2	45.50	2	92.00	2
	779	58051	62.67	3	10.00	3	8.00	3	32.06	4	9.00	4	17.89	4	18.00	4
	780	55437	-	-	11.56	3	4.67	3	22.70	3	19.56	2	12.19	3	30.67	3
275 - 366	296	9766.8	-	-	5.89	2	31.39	2	30.94	2	49.00	2	51.00	2	67.11	2
	299	29163	-	-	2.39	2	3.51	2	1.50	2	3.56	2	4.39	2	3.00	2
	705	26824	8.71	2	12.00	2	14.28	2	1.44	2	5.50	2	6.22	2	13.00	2
	706	65479	9.33	3	5.89	3	7.25	4	0.67	4	1.75	4	0.25	4	9.00	4
	707	10180	46.80	2	52.89	2	24.00	2	5.33	2	8.00	2	13.07	2	10.50	2
	715	17608	12.78	2	1.14	2	0.00	2	3.00	2	0.44	2	0.89	2	9.14	2
	716	74145	11.76	5	7.89	4	5.39	4	1.94	4	5.21	4	5.11	4	7.86	4
367 - 549	708	17333	59.50	2	626.89	2	23.70	3	0.44	2	3.94	2	22.00	2	3.10	2
	711	81574	3.92	4	0.60	5	0.78	5	0.16	5	0.58	5	2.60	5	1.60	5
	712	100557	2.00	6	3.60	5	1.76	6	1.32	6	2.38	5	1.50	6	2.83	6
	713	117064	2.98	7	4.82	6	3.57	7	2.95	7	5.00	6	2.67	6	4.96	7
	714	147741	3.99	9	3.64	7	4.19	9	4.86	9	2.81	9	3.89	9	3.36	9
550 - 731	709	20221	13.00	2	-	-	7.00	2	0.89	2	3.50	2	5.50	2	8.80	2
732 - 914	710	21460	-	-	-	-	-	-	0.00	2	-	-	-	-	-	-

Table 8. Mean weight per tow and number of sets by stratum from Canadian RV surveys in Subdivision 3Ps from 1996 to 2002.

		Year	1996		1997		1998		1999		2000		2001		2002	
Depth range	Stratum	Units	Weight	Sets	Weight	Sets	Weight	Sets	Weight	Sets	Weight	Sets	Weight	Sets	Weight	Sets
<=56	314	133984	0.58	8	0.14	7	2.87	7	7.89	8	5.10	7	1.56	7	1.55	8
	320	181581	4.13	10	0.45	9	7.31	11	10.90	8	14.53	11	8.91	10	26.77	10
57 - 91	293	21872	-	-	0.01	2	0.08	2	0.67	2	0.05	2	0.00	2	0.11	2
	308	15407	0.80	2	0.19	2	0.14	2	12.35	2	7.87	2	3.70	2	2.17	2
	312	37417	1.62	3	0.03	2	1.64	2	6.40	2	2.25	2	2.17	2	0.98	2
	315	113763	15.03	6	1.55	6	13.85	7	9.74	7	31.99	7	18.42	7	9.98	7
	321	163560	2.27	9	1.33	9	1.45	10	7.88	9	17.05	10	1.56	9	1.14	10
	325	129858	1.89	9	2.80	6	3.50	8	5.79	8	10.45	8	9.16	8	2.83	8
	326	22835	2.53	2	0.55	2	2.15	2	2.16	2	6.38	2	11.68	2	2.45	2
	783	31501	-	-	0.00	2	0.04	2	0.23	2	0.20	2	1.42	2	0.55	2
93 - 183	294	18571	-	-	0.04	2	1.35	2	0.98	2	4.04	2	1.73	2	0.96	2
	297	20909	-	-	1.25	2	1.59	2	2.46	2	4.01	2	0.48	2	1.60	2
	307	54337	0.24	4	0.00	3	1.82	3	3.30	3	1.40	3	1.28	3	0.10	3
	311	43607	1.85	3	11.98	2	13.72	3	13.37	3	33.63	3	3.30	3	8.98	3
	317	26549	26.10	2	2.38	2	35.28	2	14.20	2	43.55	2	124.30	2	4.50	2
	319	135360	26.90	8	4.89	8	35.15	8	15.85	8	7.00	8	33.44	8	24.73	8
	322	215558	2.76	11	0.82	11	0.38	13	5.62	12	9.34	11	2.27	12	0.63	13
	323	95743	6.80	5	1.40	4	4.99	6	13.13	6	25.40	5	8.76	6	3.25	6
	324	67955	5.87	3	1.17	3	0.58	4	11.22	4	0.18	4	0.19	4	1.90	4
	781	61352	4.23	2	0.21	4	0.14	4	1.14	4	0.23	4	1.03	4	0.14	4
	782	25174	-	-	0.75	2	0.51	2	1.50	2	2.38	2	0.45	2	2.50	2
184 - 274	295	28750	-	-	5.13	2	5.46	2	6.64	2	13.12	2	2.27	2	3.47	2
	298	23523	-	-	2.33	2	3.44	2	0.93	2	1.37	2	2.05	2	4.70	2
	300	29851	-	-	0.40	2	1.63	2	0.60	2	0.16	2	0.31	2	0.08	2
	306	49935	0.76	3	0.63	3	0.29	3	1.52	3	0.65	3	0.55	3	0.88	3
	309	40718	1.43	3	0.66	2	1.89	2	0.06	2	2.23	2	2.68	2	1.19	2
	310	23385	2.50	2	3.26	2	10.22	2	2.95	2	3.84	2	18.03	2	3.10	2
	313	22698	3.91	2	2.18	2	12.69	2	1.60	2	2.33	2	13.59	2	9.08	2
	316	25999	12.75	2	38.68	2	28.80	2	0.70	2	0.00	2	3.70	2	43.23	2
	318	17745	10.13	2	12.62	2	15.78	2	2.43	2	2.58	2	25.88	2	50.60	2
	779	58051	6.15	3	1.15	3	1.05	3	3.97	4	0.55	4	1.75	4	0.89	4
	780	55437	-	-	0.72	3	0.43	3	2.58	3	2.00	2	1.67	3	2.25	3
275 - 366	296	9766.8	-	-	1.73	2	10.55	2	8.29	2	18.63	2	23.93	2	27.51	2
	299	29163	-	-	0.62	2	0.87	2	1.75	2	1.73	2	1.66	2	0.14	2
	705	26824	5.22	2	5.35	2	5.31	2	0.27	2	1.88	2	0.93	2	8.52	2
	706	65479	3.10	3	2.35	3	4.06	4	0.24	4	0.76	4	0.01	4	4.90	4
	707	10180	11.48	2	14.91	2	11.51	2	2.00	2	5.05	2	6.29	2	4.97	2
	715	17608	7.81	2	0.32	2	0.00	2	1.04	2	0.01	2	0.46	2	2.69	2
	716	74145	3.89	5	3.06	4	2.46	4	0.83	4	1.84	4	3.54	4	4.30	4
367 - 549	708	17333	22.15	2	189.67	2	6.59	3	0.38	2	1.79	2	13.43	2	1.24	2
	711	81574	0.83	4	0.04	5	0.06	5	0.01	5	0.26	5	1.98	5	0.46	5
	712	100557	0.50	6	0.79	5	0.17	6	0.35	6	0.47	5	0.22	6	0.25	6
	713	117064	0.76	7	1.08	6	0.39	7	0.32	7	0.69	6	0.48	6	0.66	7
	714	147741	0.58	9	0.90	7	0.69	9	0.50	9	0.30	9	0.45	9	0.95	9
550 - 731	709	20221	4.03	2	-	-	1.58	2	0.29	2	2.25	2	2.60	2	3.47	2
732 - 914	710	21460	-	-	-	-	-	-	0.00	2	-	-	-	-	-	-

Table 9. Abundance index (millions) at age for American plaice in Subdivision 3Ps from Canadian research vessel surveys from 1983 to 2002. Data from 1983 to 1995 are Campelen equivalents.

age/year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993 Feb	1993 Apr	1994	1995	1996	1997	1998	1999	2000	2001	2002
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.35	1.41	0.05	0.03
2	0.12	0.27	0.00	0.00	0.00	0.00	0.00	0.11	0.71	0.14	0.00	0.00	0.23	0.00	4.67	0.37	0.60	2.17	34.60	5.95	1.54
3	2.84	0.00	0.48	1.02	2.14	1.21	1.98	0.36	2.82	0.40	0.32	0.00	0.19	0.00	11.94	7.22	0.62	3.02	20.66	24.40	9.12
4	22.02	3.36	7.59	11.80	6.23	7.60	6.58	3.71	5.75	1.02	0.44	0.06	3.23	0.47	20.54	6.73	6.19	4.65	11.83	9.43	15.36
5	101.98	31.20	40.16	34.27	32.45	32.44	18.77	11.97	22.55	8.26	0.78	3.07	7.38	4.95	24.91	7.98	8.78	16.04	11.71	4.46	4.38
6	142.59	78.99	81.77	90.21	67.85	61.67	39.89	10.37	40.00	14.96	6.21	12.07	9.99	11.72	11.54	7.37	6.12	14.80	17.52	6.93	2.65
7	112.32	48.34	73.58	84.68	75.07	42.40	39.95	9.31	33.97	14.12	6.67	11.35	9.02	14.94	10.90	7.36	10.31	9.85	12.79	7.21	3.88
8	83.09	21.66	26.51	32.29	50.28	35.73	14.56	6.17	26.62	4.88	3.48	6.86	6.73	8.67	3.92	3.62	7.16	6.59	8.90	7.07	4.92
9	35.25	13.19	21.71	12.94	21.92	15.24	9.82	3.84	11.37	3.42	1.72	3.28	3.42	5.24	2.14	1.62	6.27	4.56	7.05	6.05	4.16
10	15.57	10.08	17.57	8.73	13.24	8.57	4.73	2.42	6.45	2.38	1.19	1.99	1.79	2.04	0.80	0.53	2.58	3.21	3.94	3.78	2.70
11	9.71	5.45	10.35	4.96	5.83	3.57	3.00	1.37	2.57	1.36	0.65	0.95	0.91	0.97	0.32	0.24	1.69	1.99	3.18	2.74	2.28
12	4.96	3.06	7.12	4.13	5.12	2.50	2.74	0.84	2.05	0.93	0.29	0.67	0.29	0.36	0.17	0.20	0.97	1.11	1.60	1.84	1.76
13	3.19	1.27	6.97	3.06	3.24	1.37	1.88	0.35	1.35	0.94	0.18	0.48	0.12	0.18	0.02	0.09	0.56	0.43	1.02	0.96	0.92
14	1.95	0.91	4.79	1.64	2.04	1.09	1.06	0.39	0.89	0.43	0.11	0.26	0.03	0.10	0.02	0.10	0.15	0.25	0.53	0.47	0.53
15	1.23	0.62	4.64	1.72	1.83	0.98	0.69	0.39	0.86	0.72	0.07	0.21	0.00	0.01	0.03	0.01	0.15	0.09	0.17	0.42	0.18
16	1.29	0.28	3.91	1.14	1.22	0.58	0.65	0.30	0.73	0.33	0.06	0.16	0.00	0.00	0.00	0.00	0.10	0.02	0.05	0.10	0.12
17	0.41	0.20	2.12	0.42	0.40	0.45	0.35	0.19	0.21	0.15	0.03	0.07	0.00	0.00	0.00	0.00	0.06	0.00	0.14	0.09	0.07
18	0.25	0.14	2.34	0.33	0.27	0.05	0.23	0.15	0.05	0.07	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06
19	0.19	0.02	0.14	0.06	0.05	0.03	0.09	0.05	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UNKNOWN	0.00	0.27	1.04	0.00	0.00	0.00	0.02	0.00	0.18	0.11	0.15	0.00	0.01	0.13	0.15	0.01	0.00	0.04	0.09	0.06	0.15
TOTAL	518.96	217.33	312.65	293.38	286.98	215.50	149.23	52.30	158.98	54.64	22.57	41.54	43.34	49.77	92.09	45.46	52.62	69.18	137.28	82.06	54.84

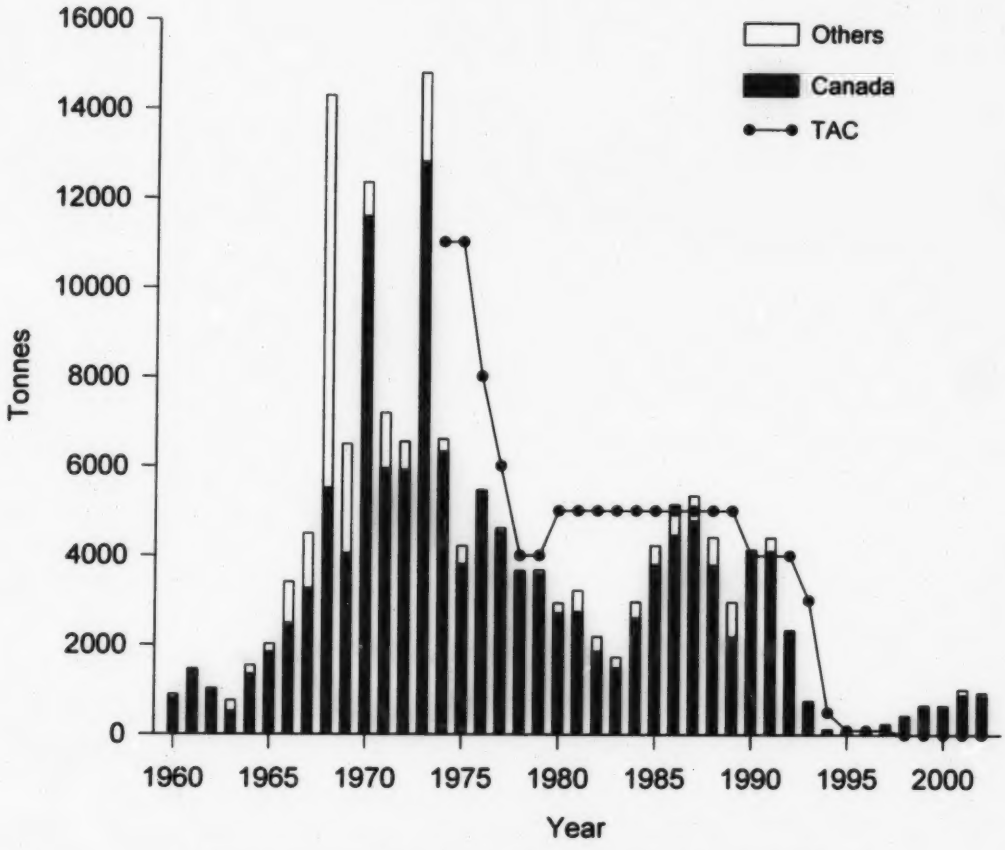


Figure 1. Total catch by Canada (black bars) and other countries (white bars) as well as total allowable catch (TAC) for each year from 1960 to 2002.

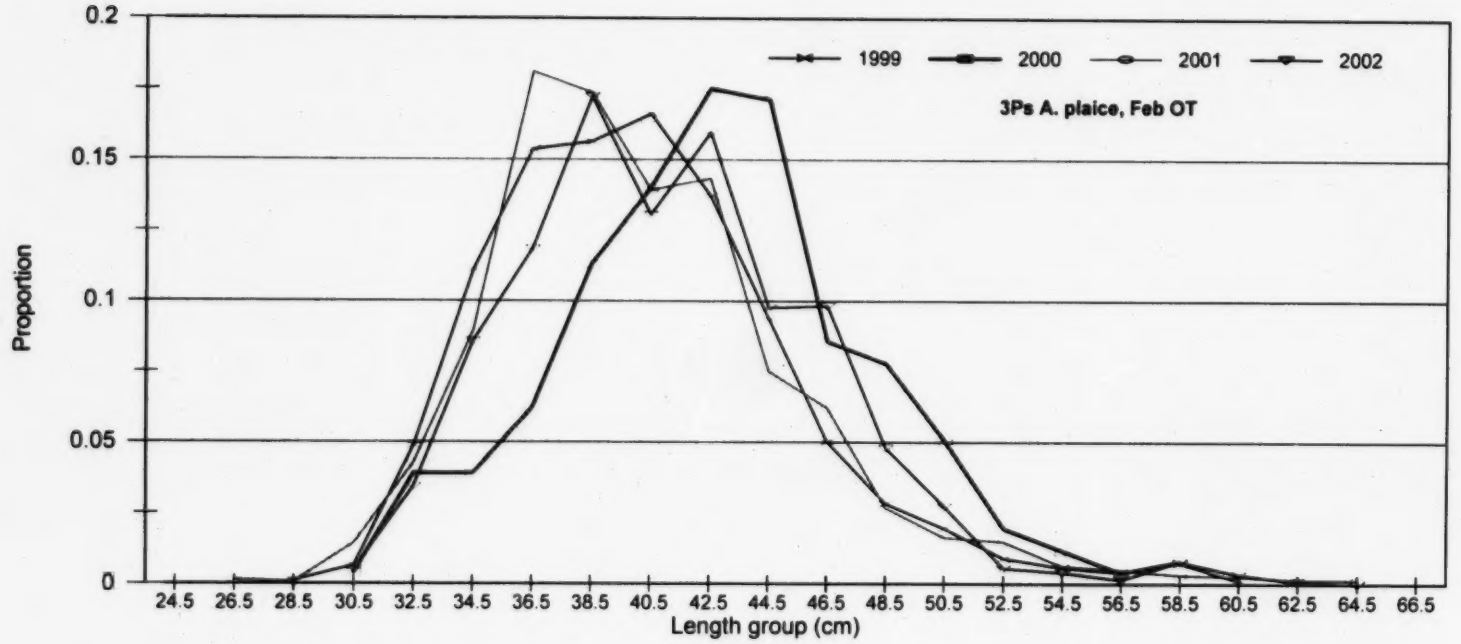


Figure 2. Comparison of proportions at length from the 1999 - 2002 Canadian fisheries (offshore OT, Feb.) for American plaice in 3Ps

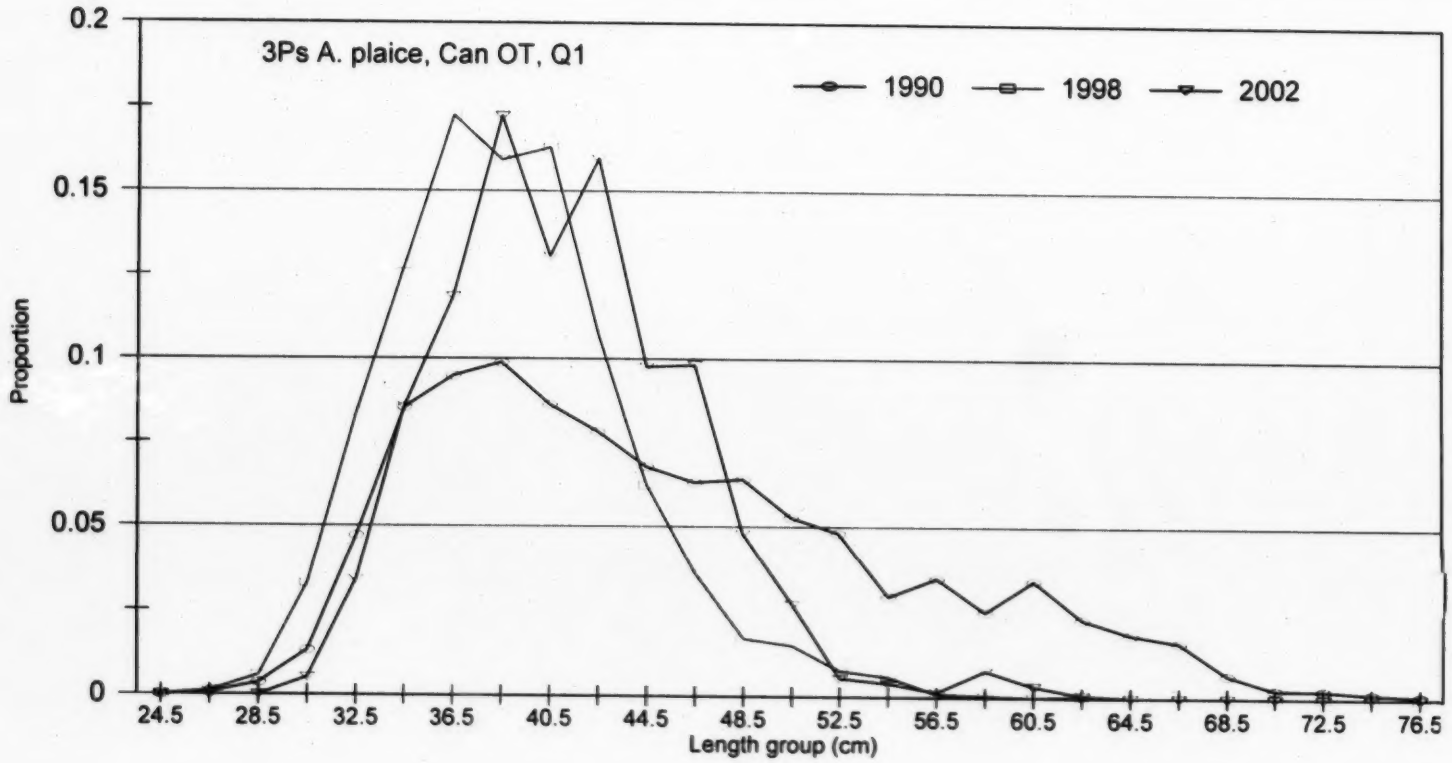


Figure 3. Comparison of length frequencies from Can OT, first quarter catches, in 1990, 1998, and 2002.

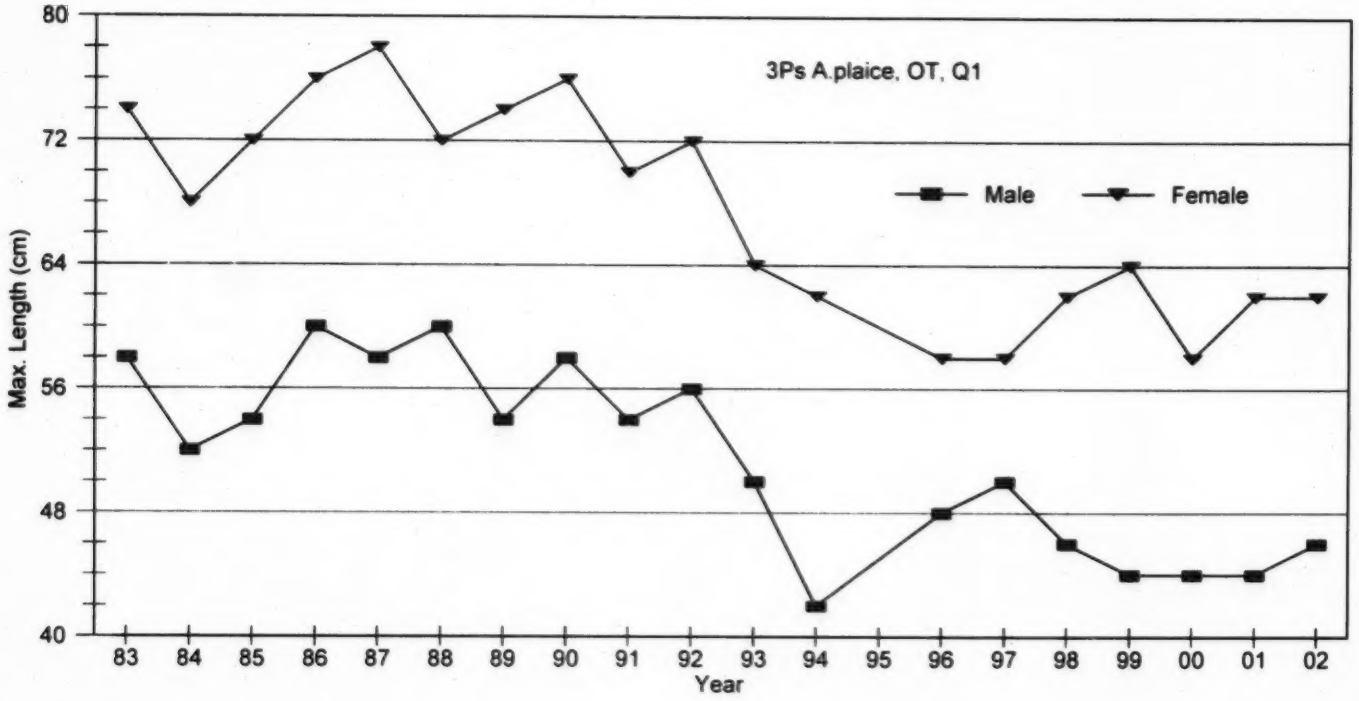


Figure 4. Maximum size of A. plaice in length frequencies from Canadian otter trawl fisheries, Subdiv 3Ps, 1983-2002.

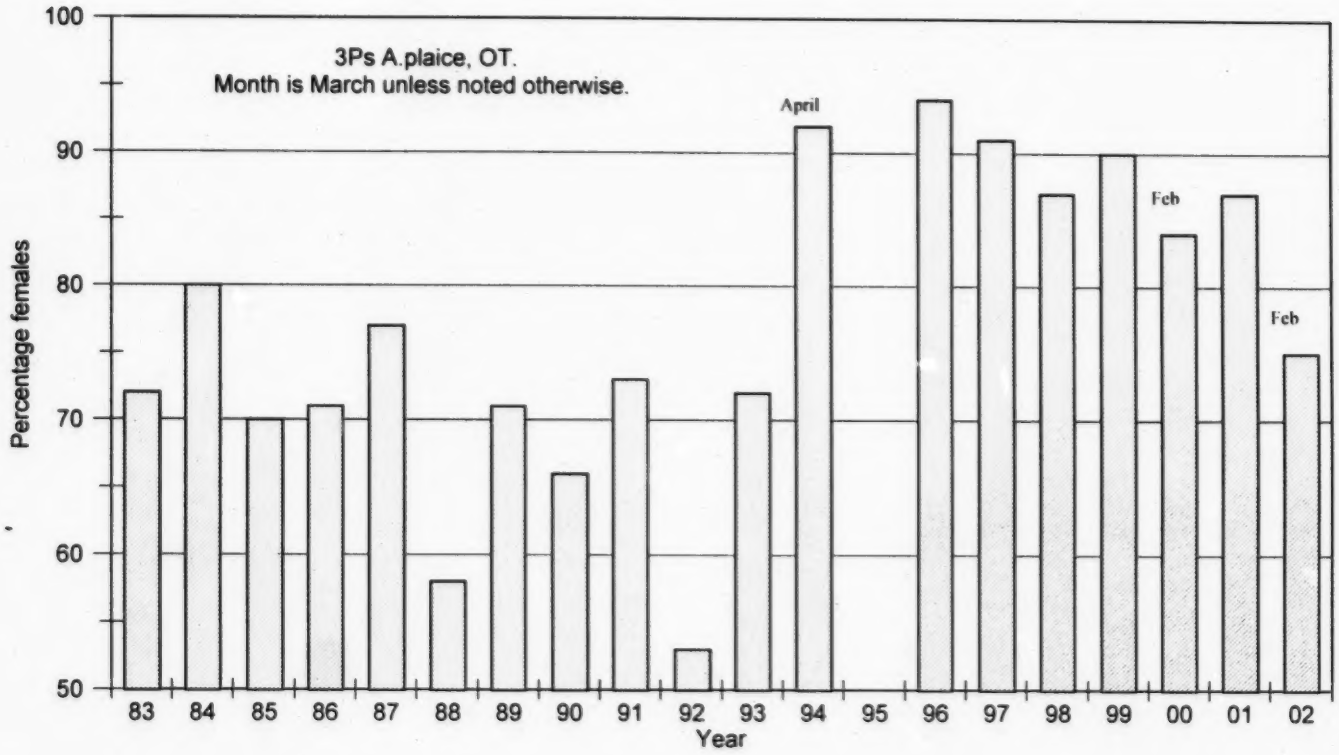


Figure 5. Percentage of female American plaice in length frequencies from Canadian OT fishery, Subdiv 3Ps, 1983-2002.

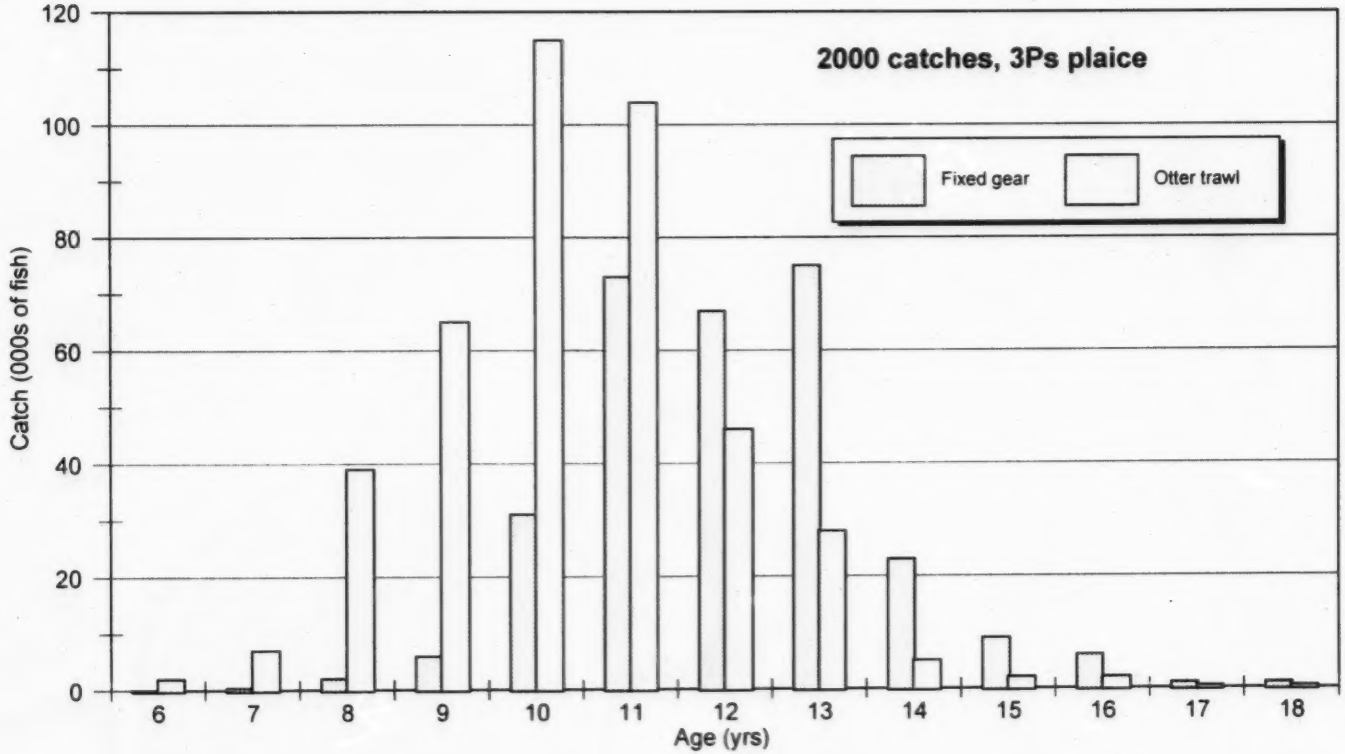


Figure 6. Comparison of age compositions from fixed gear and otter trawl, for A. plaice fisheries in 3Ps in 2000.

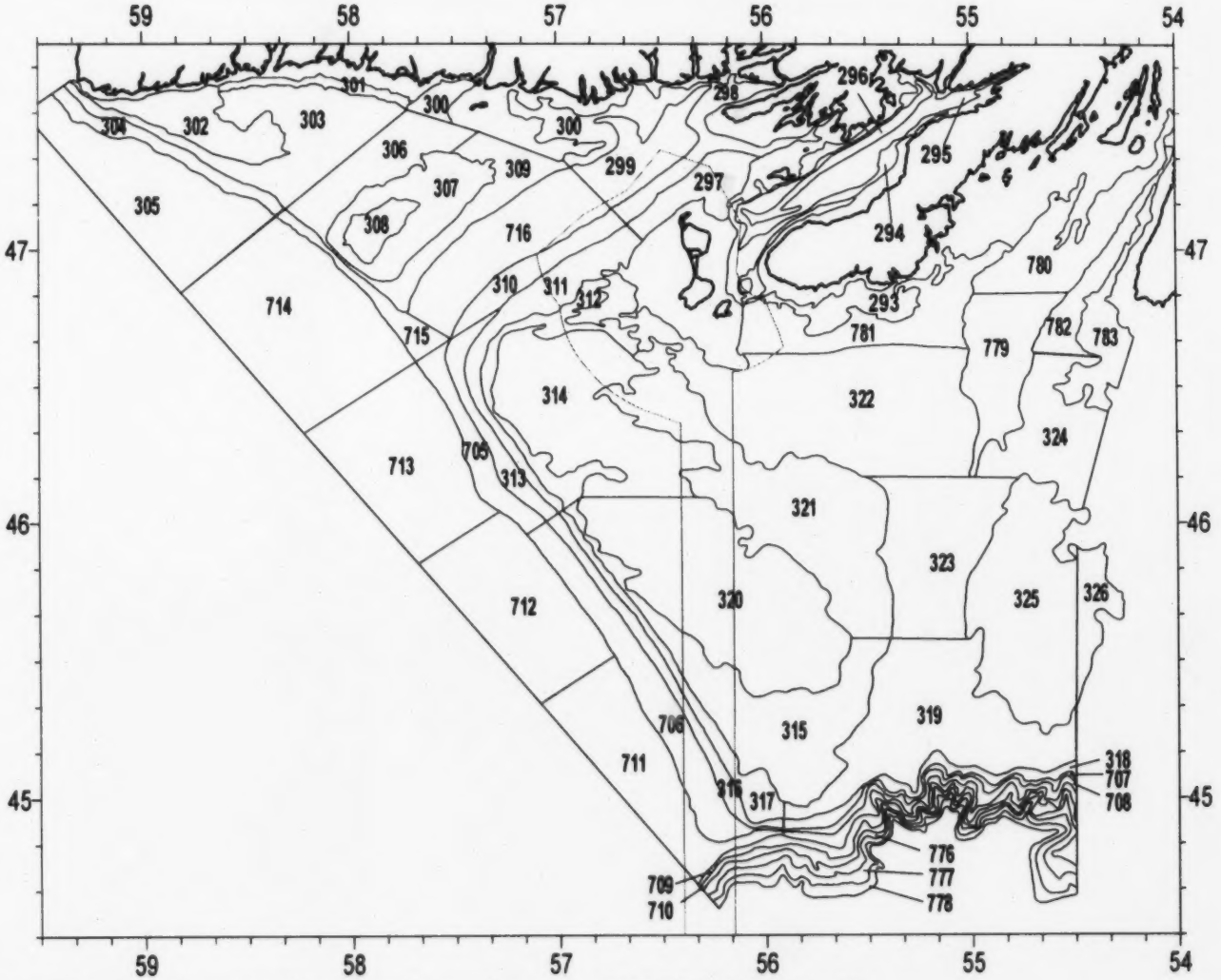
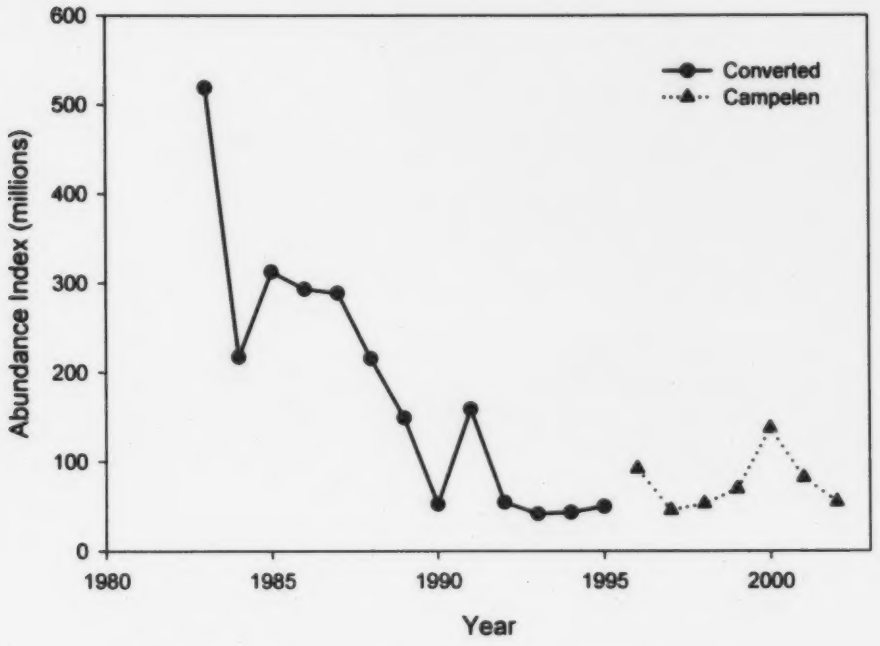


Figure 7. Stratification scheme used in research vessel surveys of NAFO Subdivision 3Ps.



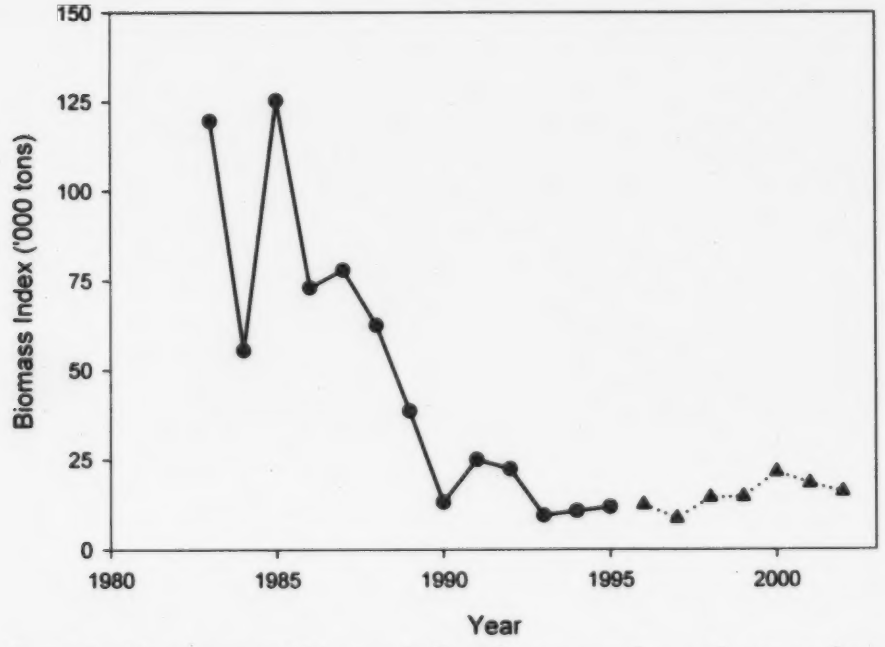


Figure 8. Abundance and biomass indices from research vessel surveys from 1983 to 2002. Converted (1983-1995) and Campelen (1996-2002) data are shown. The 1993 data are from the April survey.

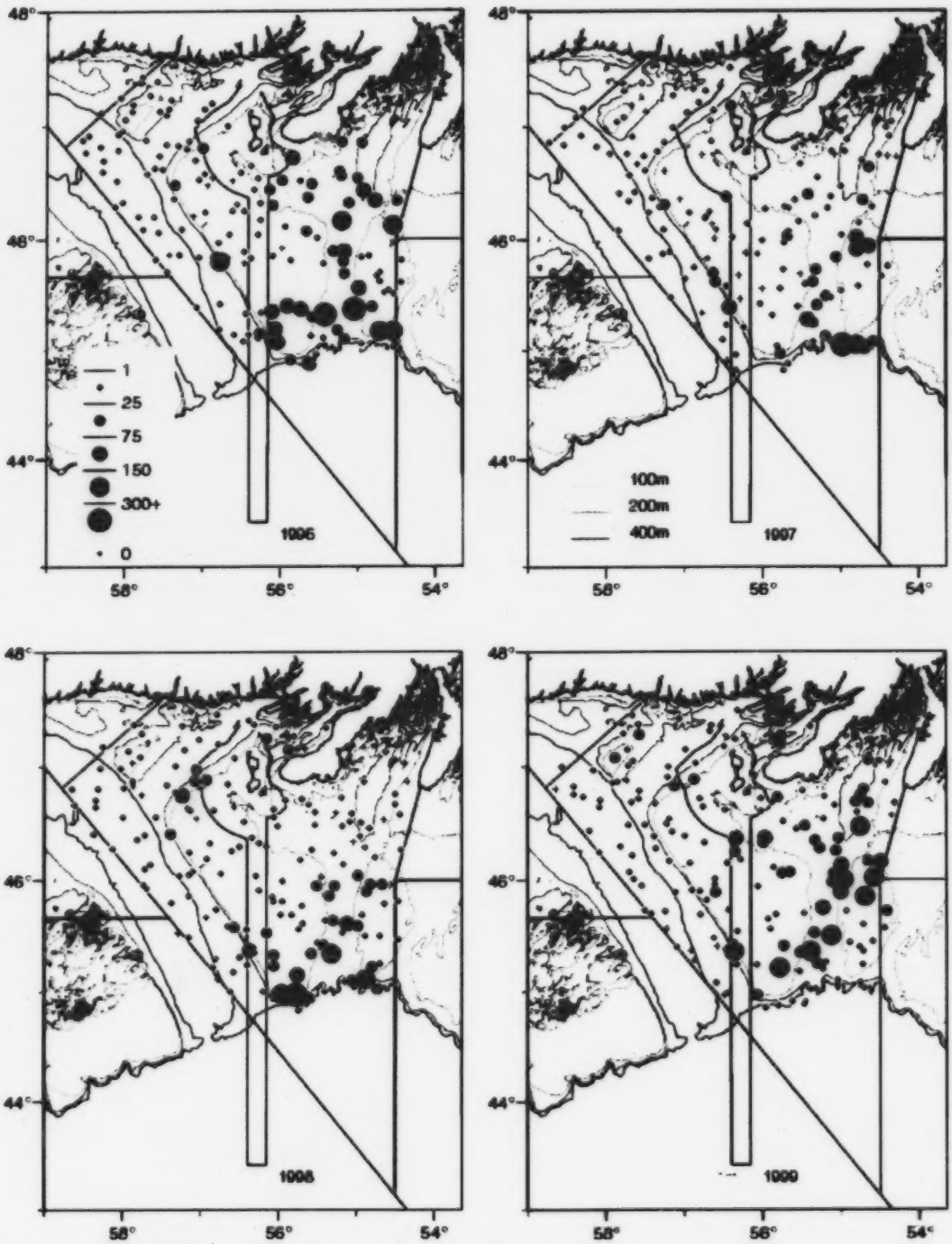


Figure 9. Distribution of American plaice (number) from research vessel surveys in NAFO Subdivision 3Ps from 1996-2002.

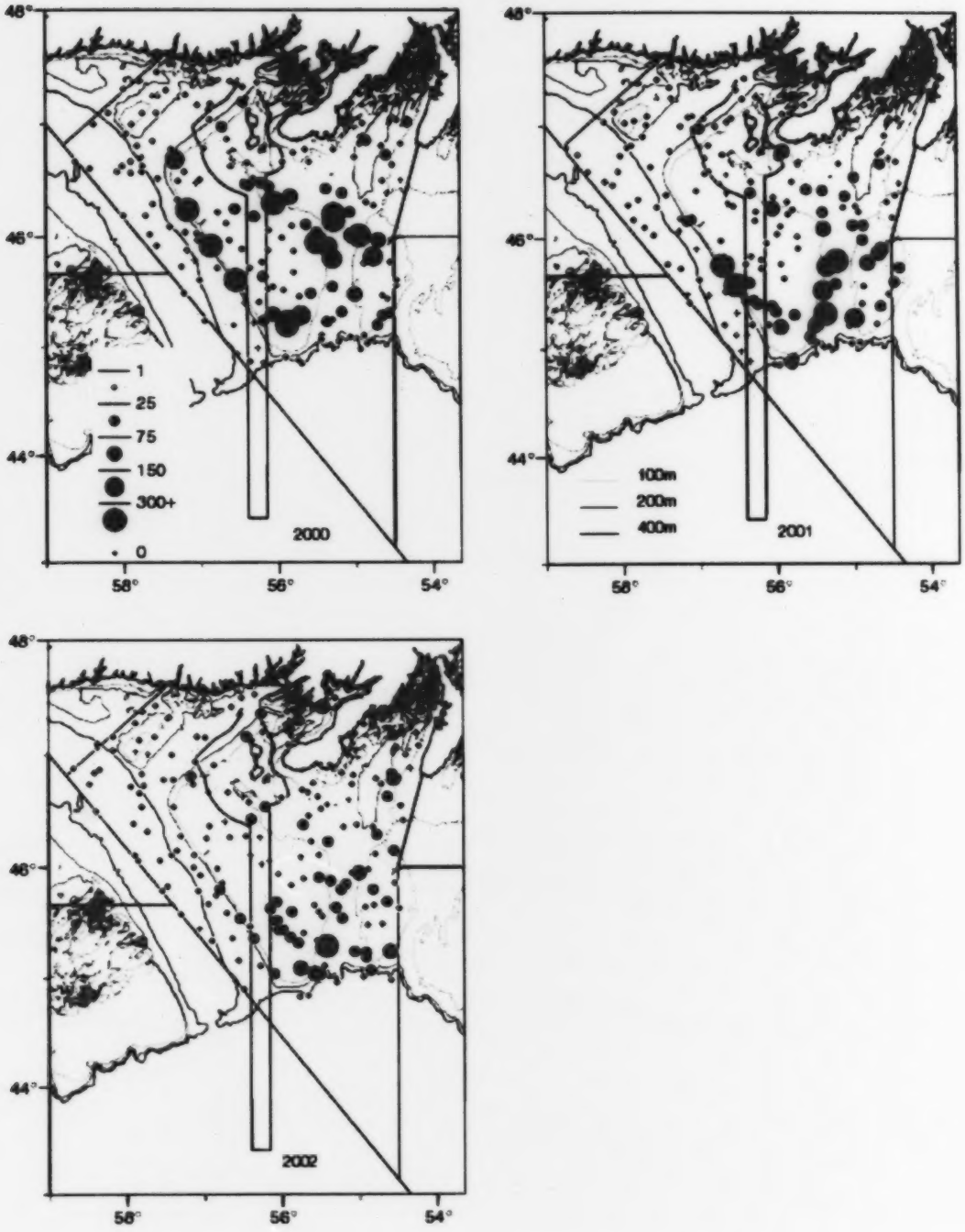


Figure 9. Cont'd.

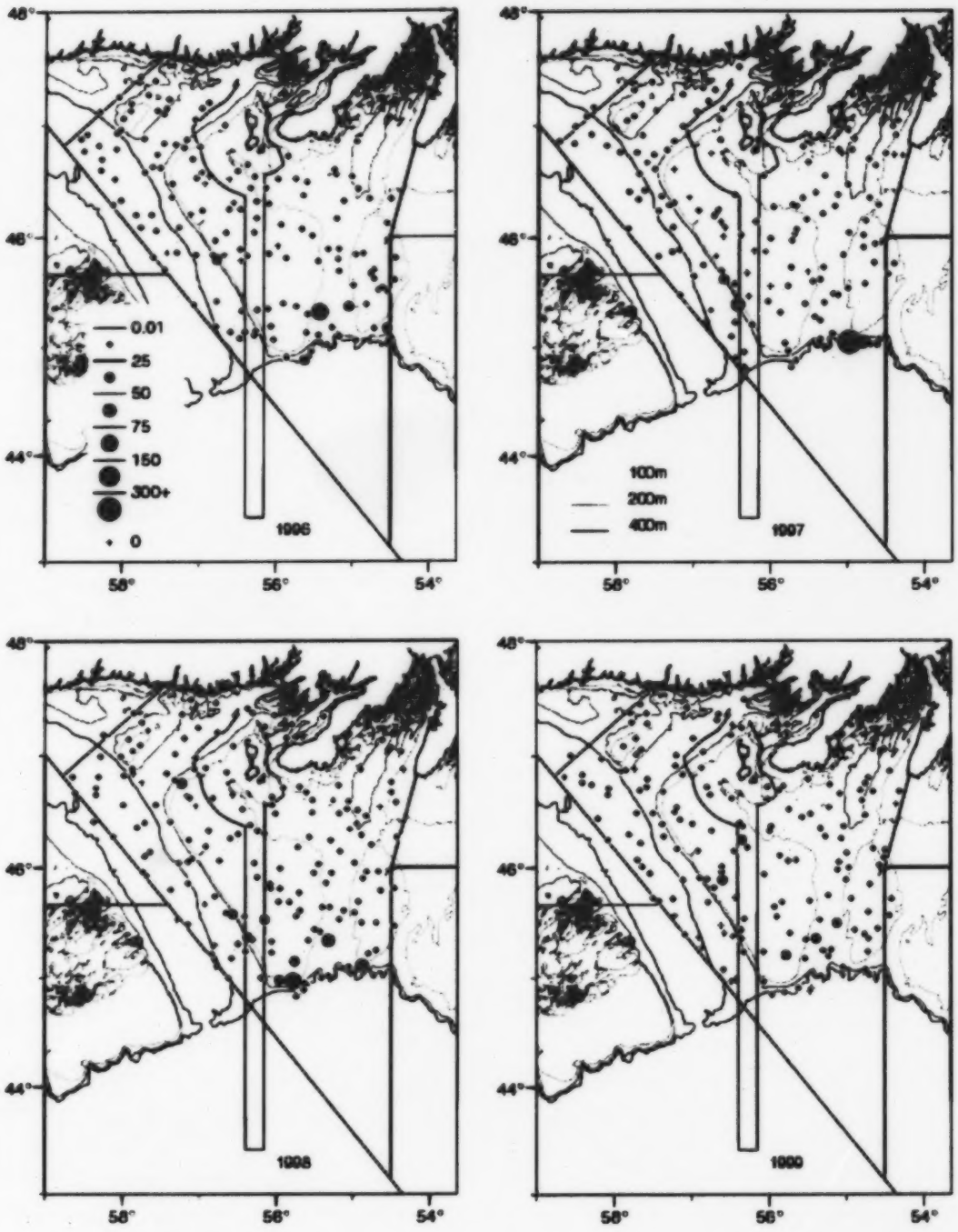


Figure 10. Distribution of American plaice (Kg) from research vessel surveys in NAFO Subdivision 3Ps from 1996-2002.

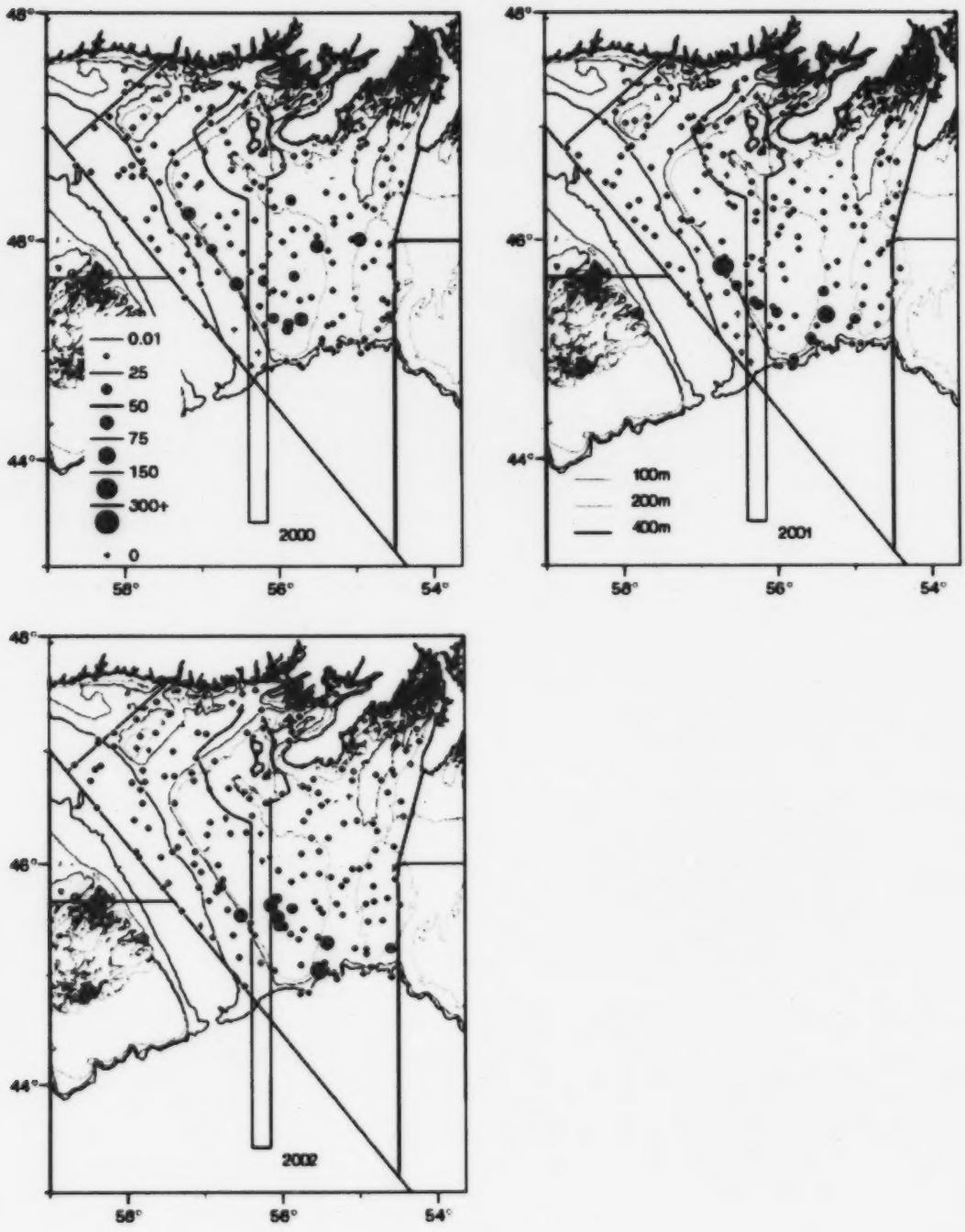


Figure 10. Cont'd.

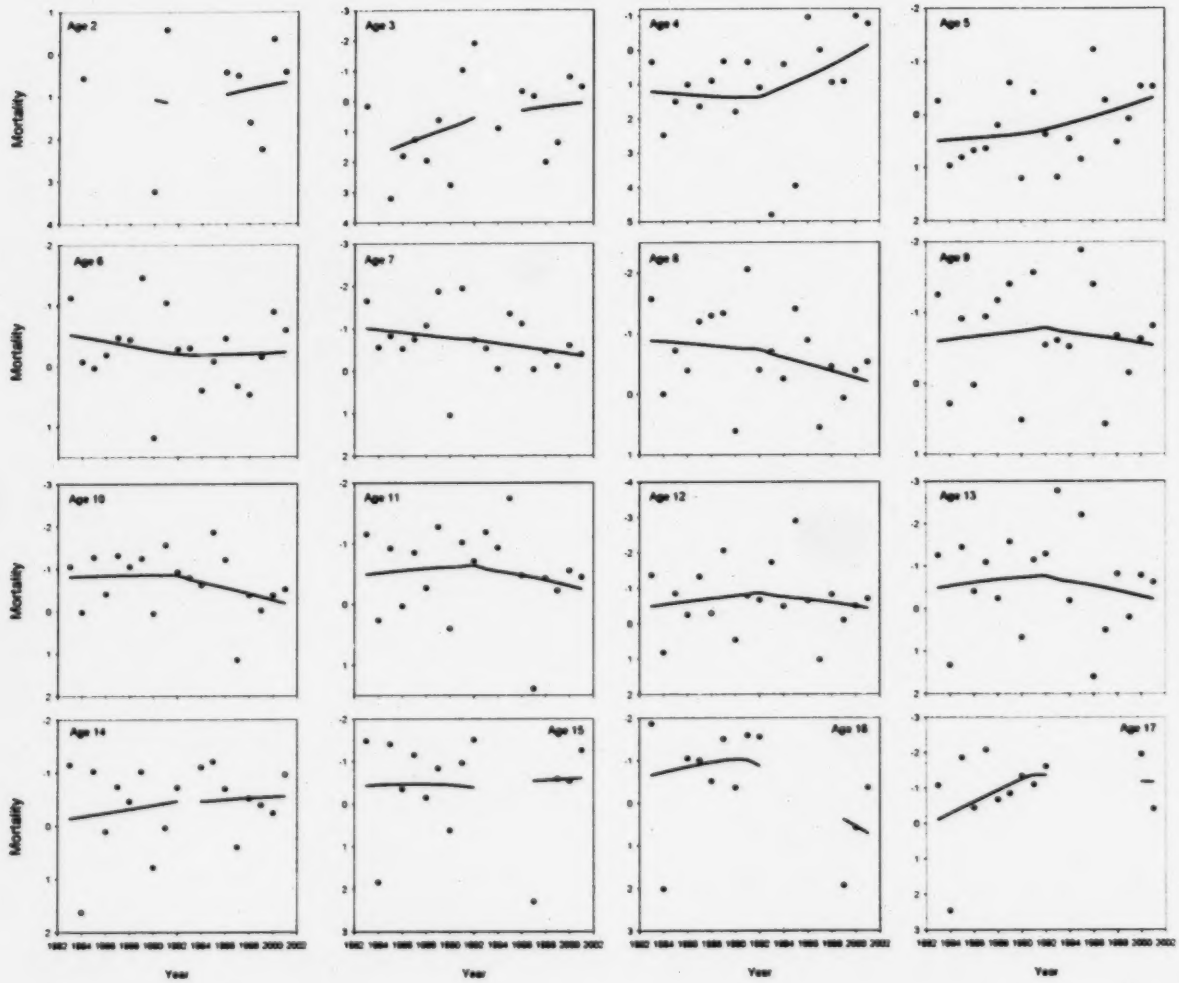


Figure 11. Estimates of mortality for ages 2 to 17 of American plaice from surveys in Subdivision 3Ps from 1983-2002.

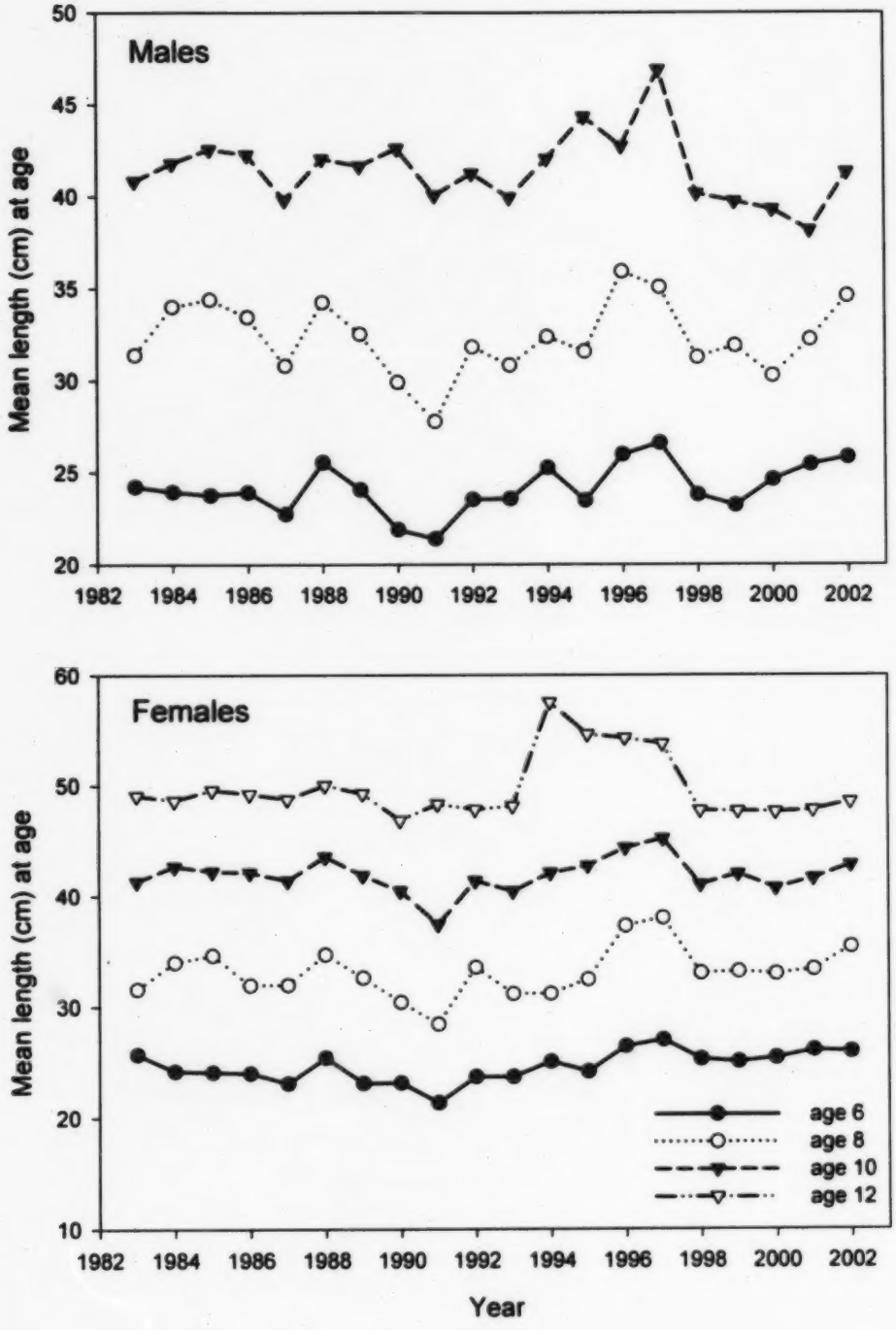


Figure 12. Mean length at age for selected ages of male and female American plaice in research vessel surveys from 1983-2002.

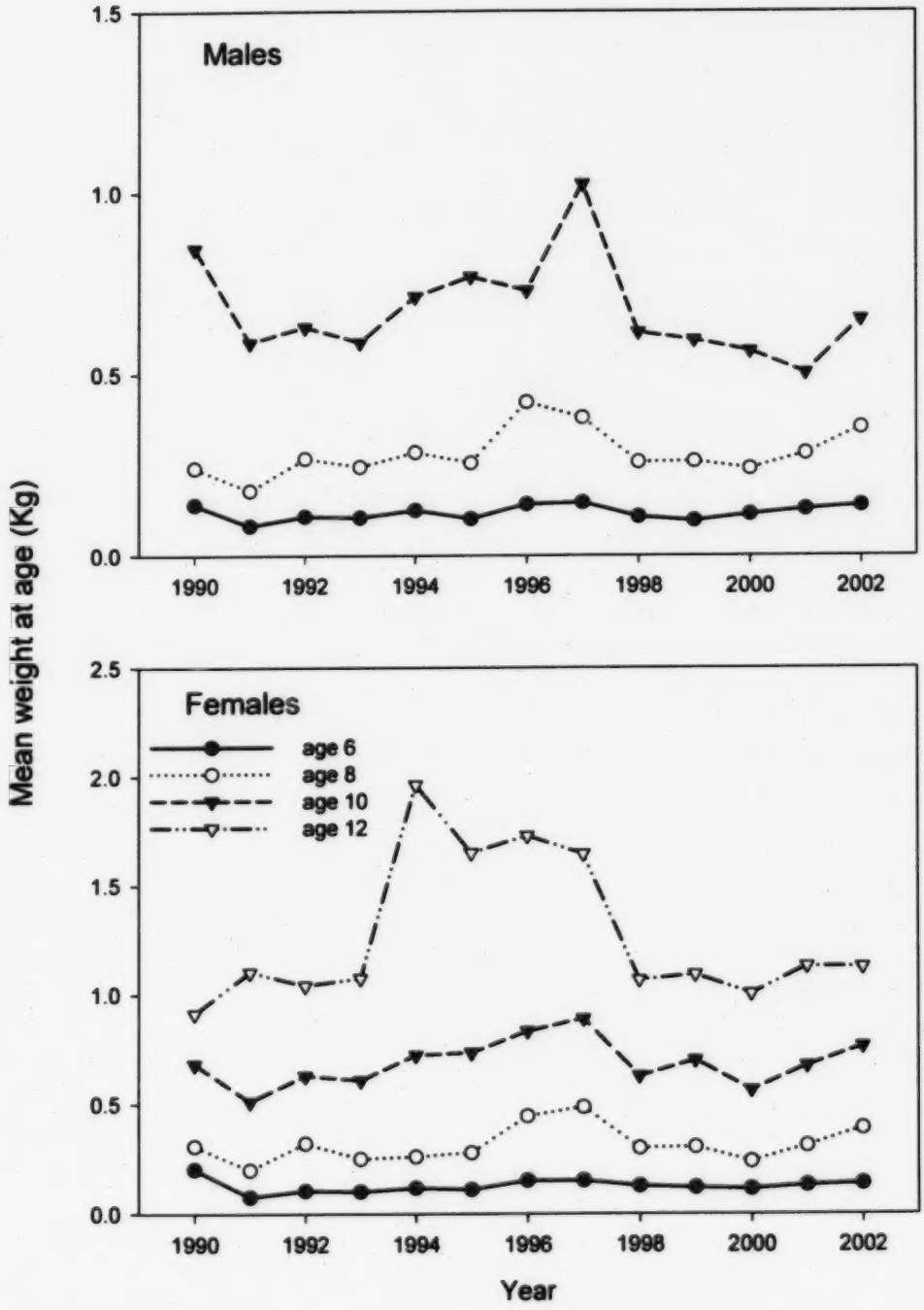


Figure 13. Mean weight at age for selected ages of male and female American plaice from research vessel surveys from 1990 to 2002.

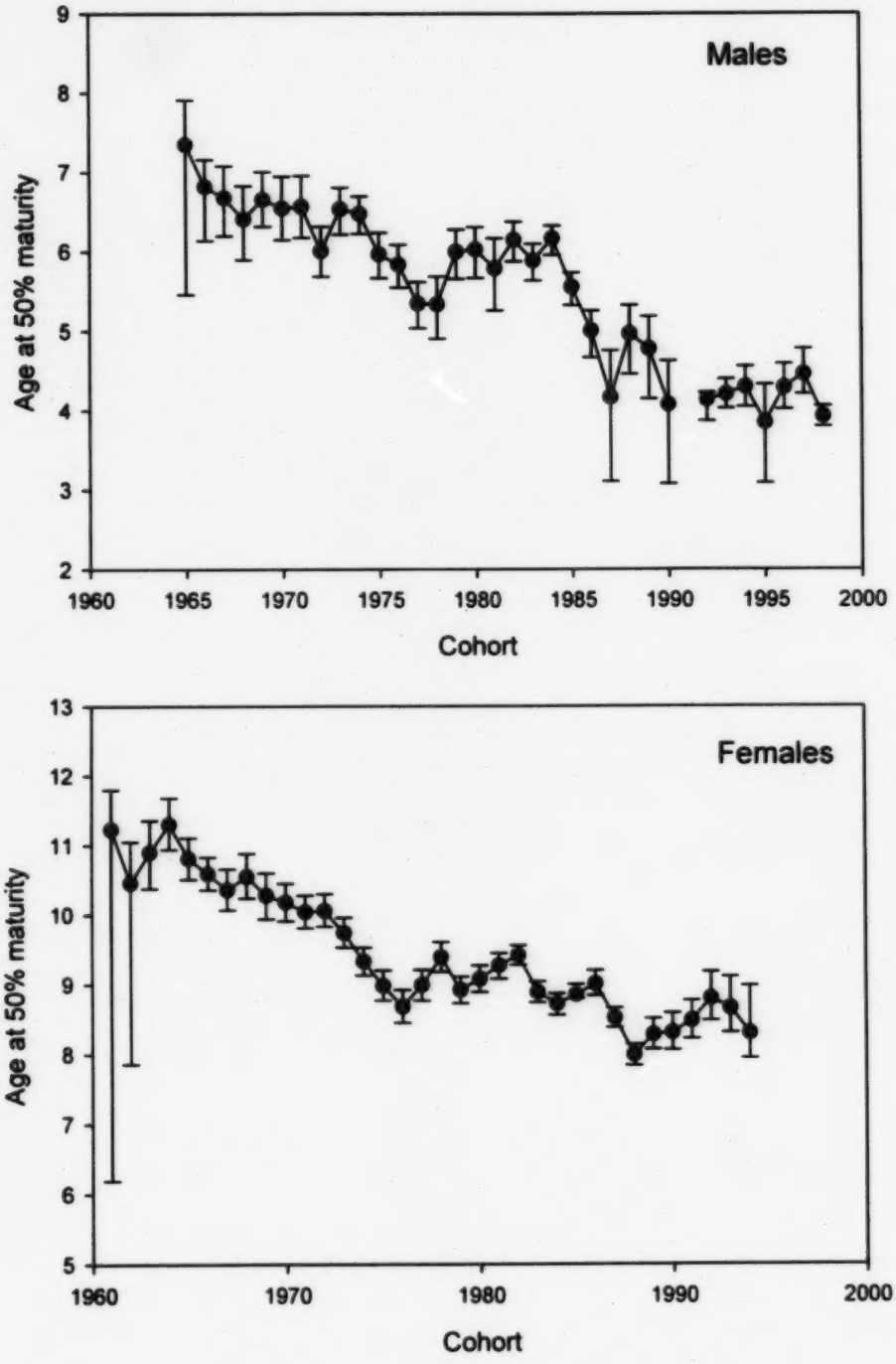
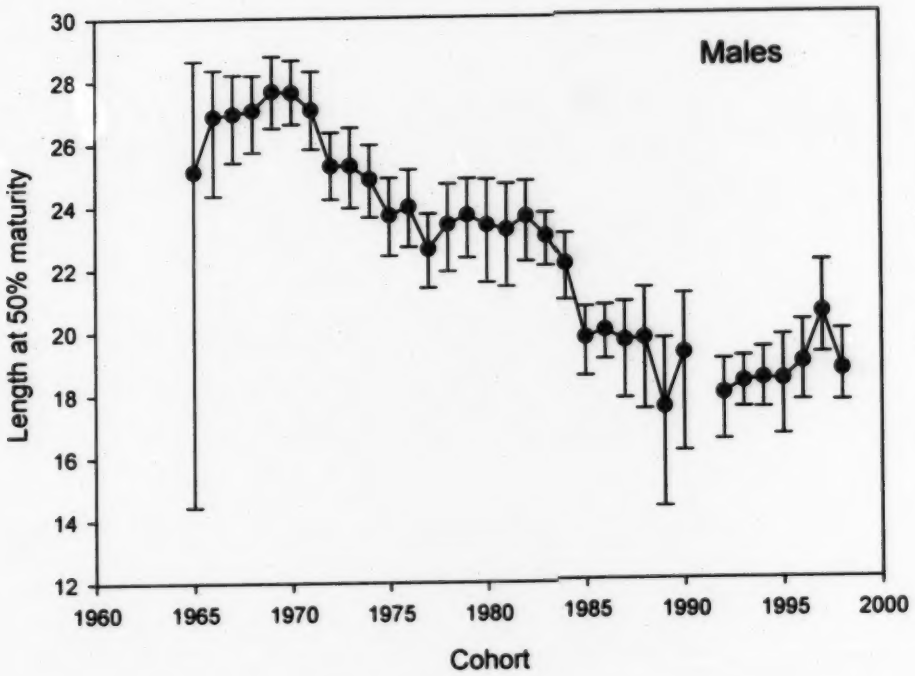


Figure 14. Age at 50% maturity (± 95% fiducial limits) for male and female American plaice.



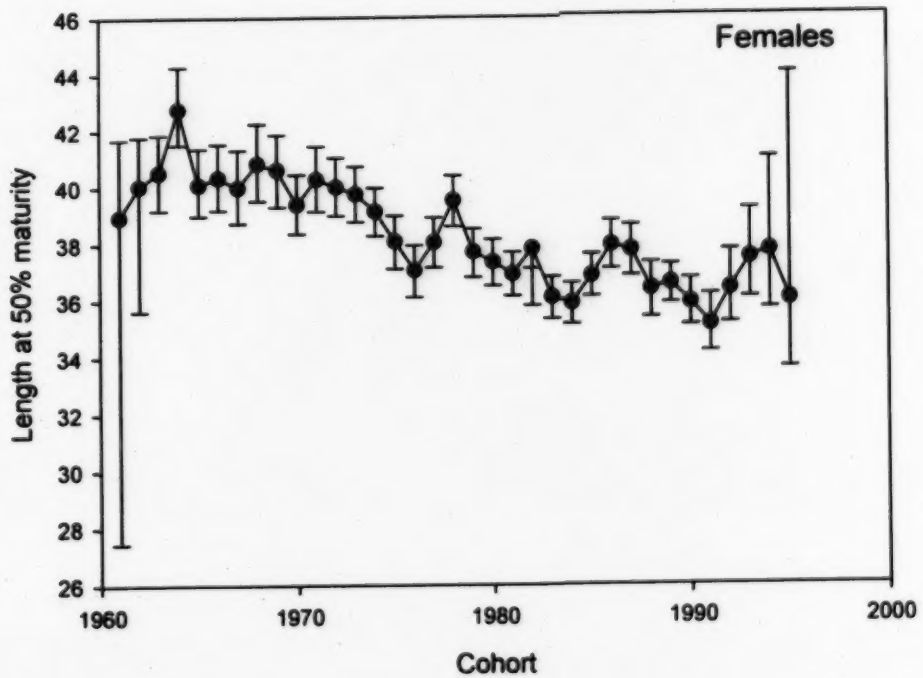


Figure 15. Length at 50% maturity (± 95% fiducial limits) for male and female American plaice.

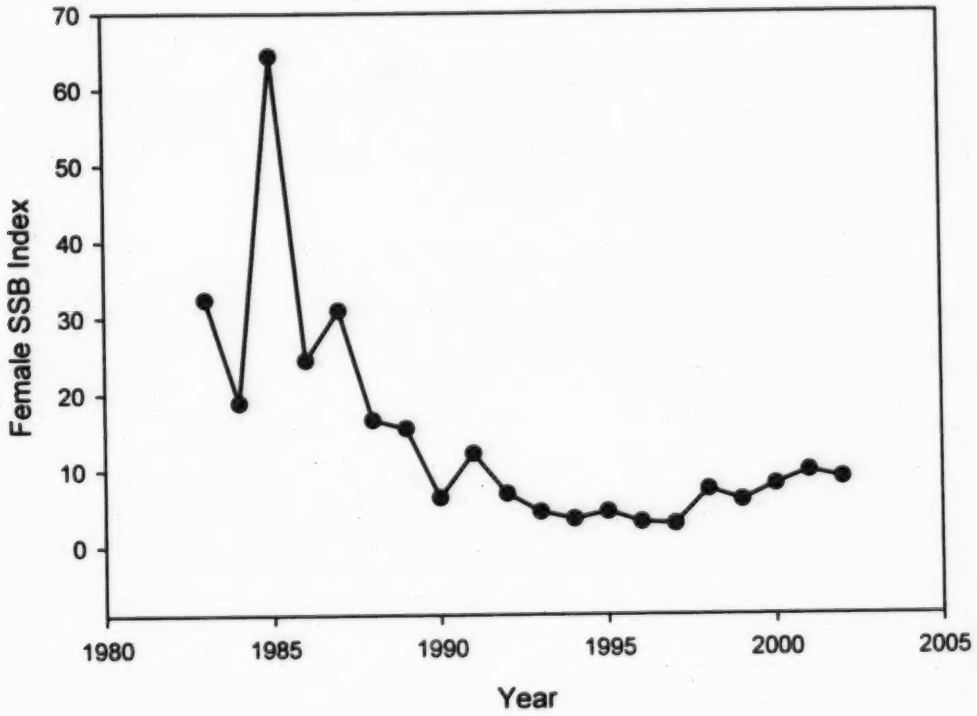
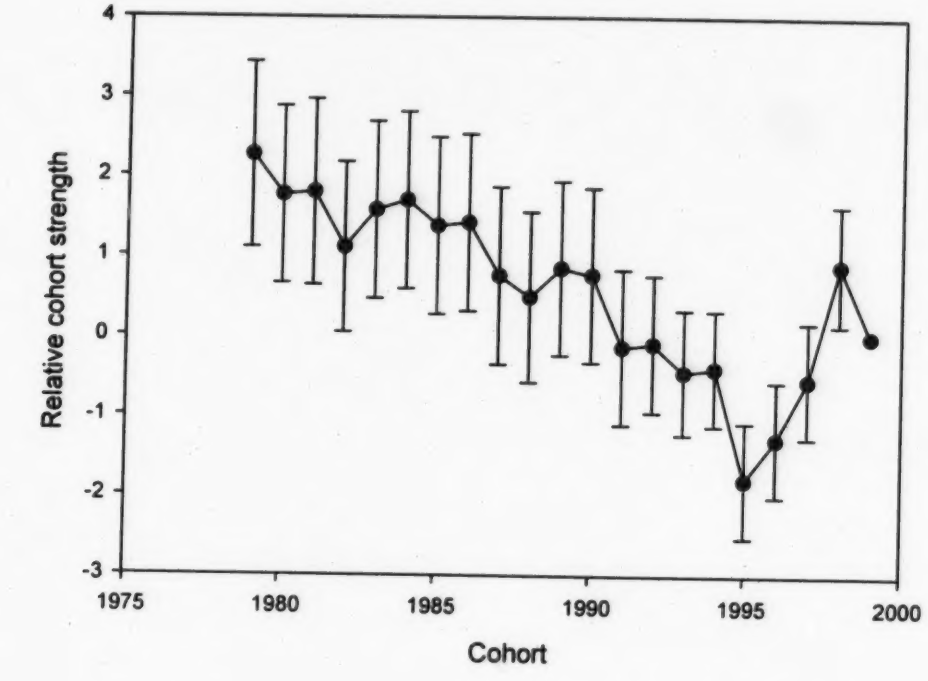


Figure 16. Index of female spawning stock biomass of American plaice from research vessel surveys from 1983 to 2002.



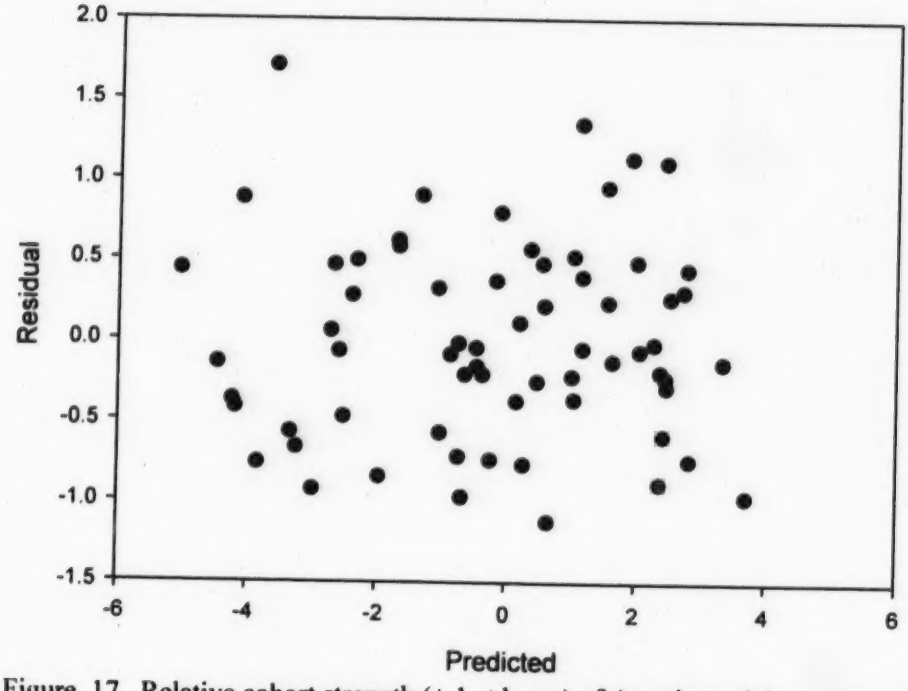


Figure 17. Relative cohort strength (± 1 std. err.) of American plaice estimated from research vessel data. The bottom panel shows the residuals from the fitted model.

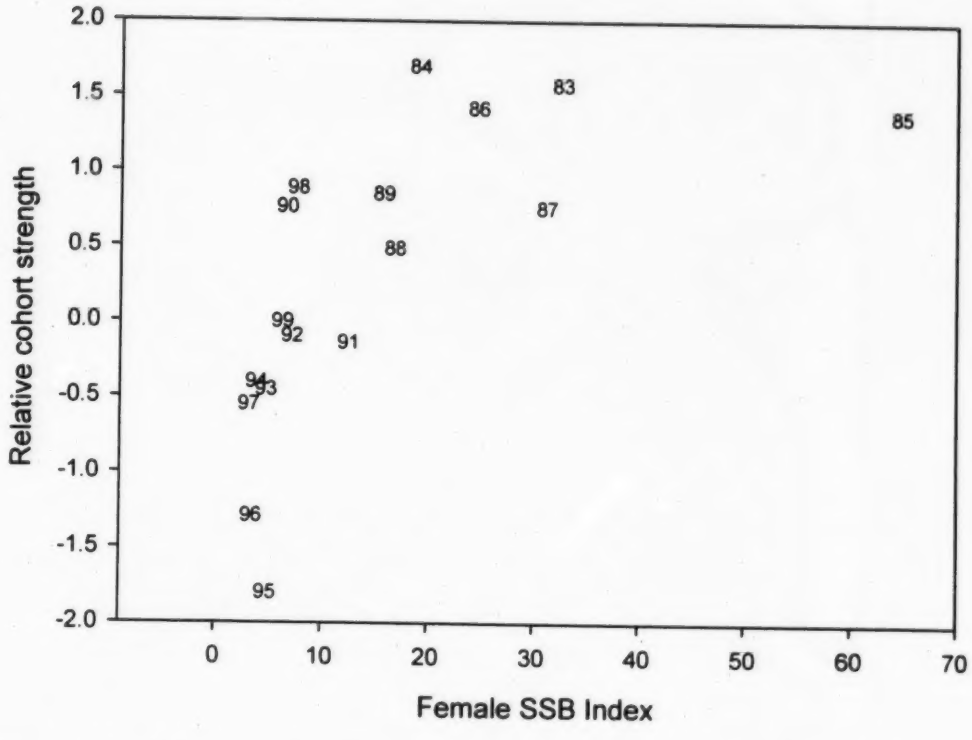


Figure 18. Relative cohort strength vs. an index of female spawning stock biomass. The symbols indicate the cohort.

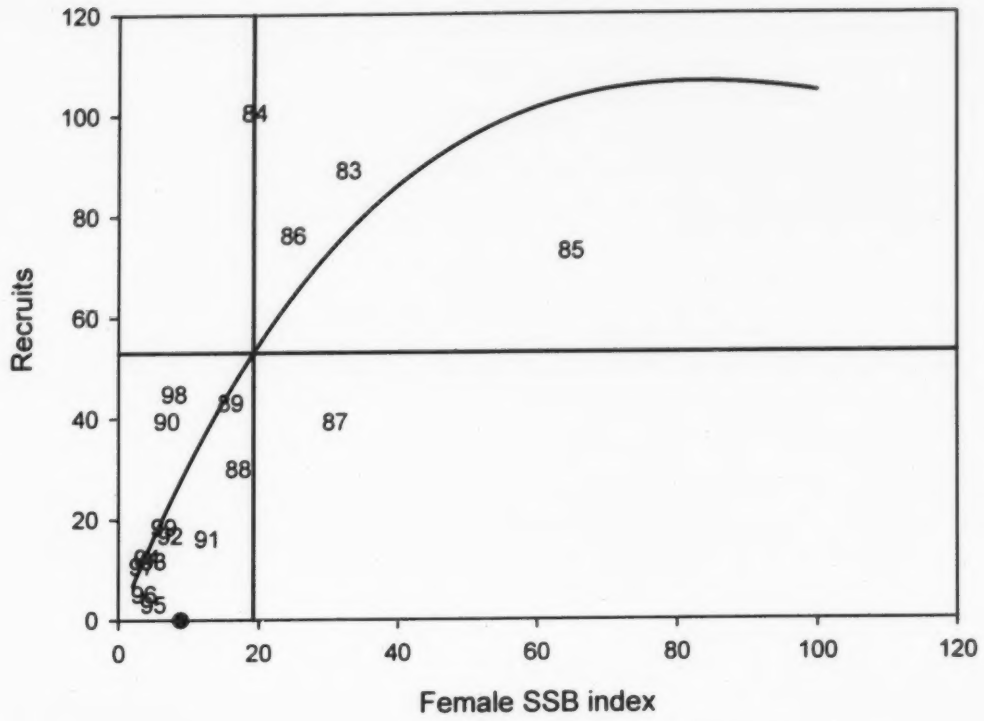


Figure 19. Stock recruit relationship for Subdivision 3Ps American plaice. The symbols show the year class strength as estimated from a relative cohort strength model. The curved line is the fitted Ricker model. The horizontal line shows 50% of the maximum estimated recruitment and the vertical line shows the SSB which is estimated to produce 50% of the maximum recruitment. The solid circle on the x-axis shows the current female SSB index.

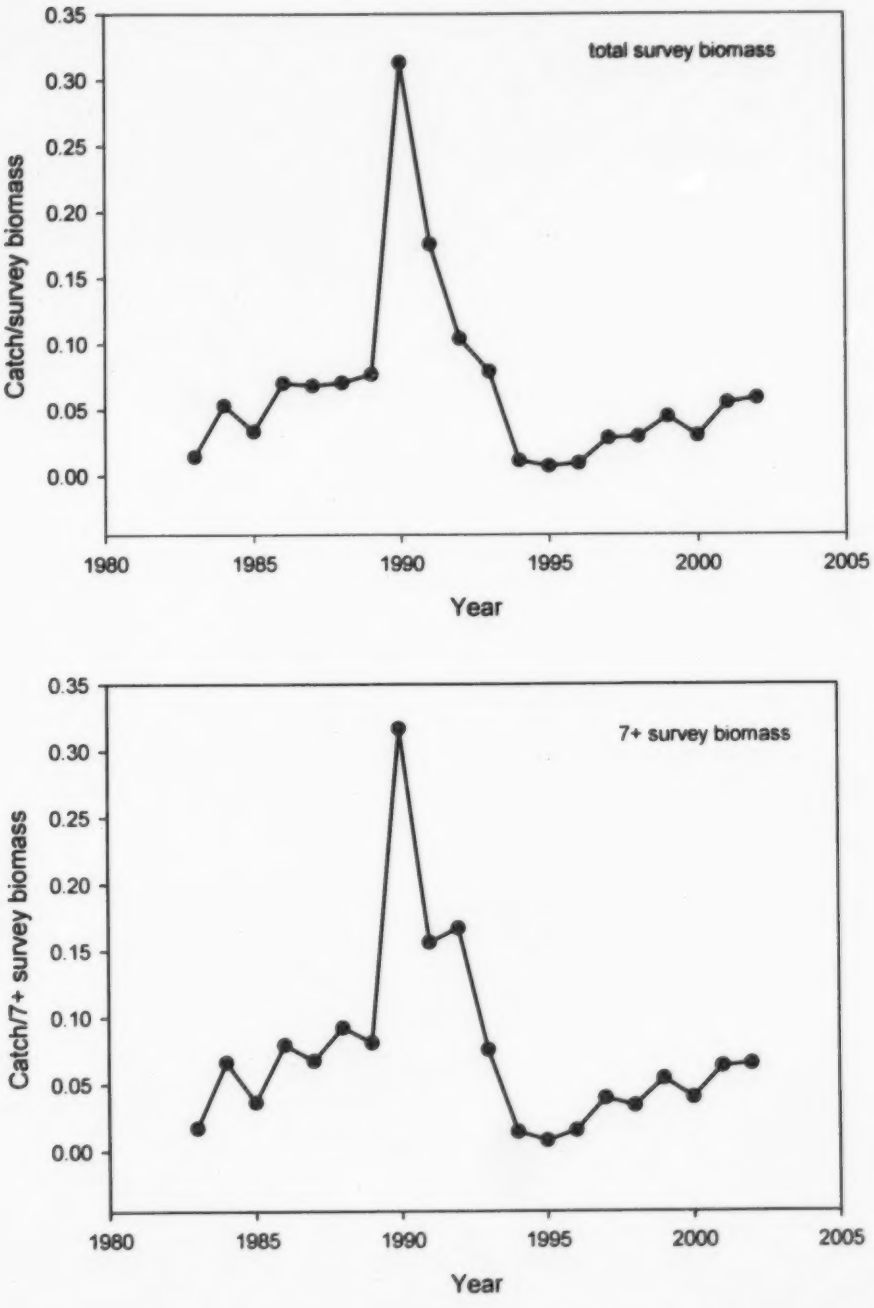


Figure 20. Catch to survey biomass ratio for American plaice in Subdivision 3Ps from 1983-2002. Data for 2002 are incomplete. Top panel shows the C/B ratio calculated using the total survey index and the bottom panel shows the C/B ratio calculated using on the 7+ or exploitable portion of the survey biomass index.